

## OPTICAL DEPILATING DEVICE

**Publication number:** JP3066387 (A)

**Publication date:** 1991-03-22

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**Classification:**

- international: **A61N5/06; A45D26/00; A61N5/06; A45D26/00; (IPC1-7): A61N5/06**

- **European:**

**Application number:** JP19890200296 19890803

**Priority number(s):** JP19890200296 19890803

**Also published as:**

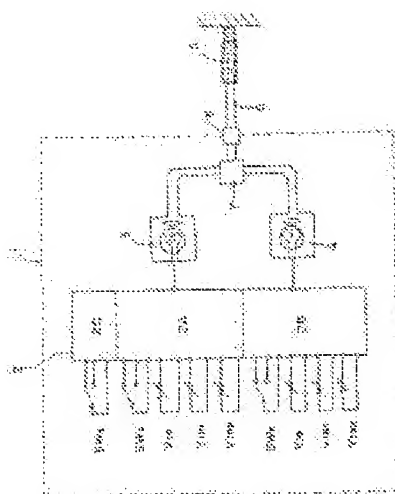
JP2854027 (B2)

## Abstract of JP 3066387 (A)

**PURPOSE:**To automatize the start of irradiation and to reduce the fatigue at the time of irradiation by providing a means for executing alternately the irradiation and the stop of an irradiation probe, and varying independently an interval of an irradiation period and a stop period on an electric control part.

**CONSTITUTION:** At the time of executing the optical depilation, a use condition of a light emission source of each color, that is, changeover switches SWR, SWB, strength setting parts VIR, VIB, irradiation period setting parts VTR1, VTB1, and stop period setting parts VTR1, VTB1 are set. In the case of radiating a red light, a red color irradiation probe 5 is installed in a photoconductor cable connector 8, and the selection of a use light source is switched to a contact position R by a switch SWS.; Also, in the case of a blue color, the switch SWS is switched to a contact position B. A red color or blue color light emission source always execute a light emission and a stop in accordance with the sequence.

Therefore, a user moves the irradiation probe to a desired part of the skin in the course of a stop period, and executes the radiation during the irradiation period for pressing and fixing it. Since the start of irradiation is determined automatically in the device, fatigue is not generated against use of many hours.



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## ⑫ 公開特許公報(A)

平3-66387

⑮ Int. Cl.<sup>5</sup>

識別記号

庁内整理番号

⑬ 公開 平成3年(1991)3月22日

A 61 N 5/06

Z

8117-4C

審査請求 未請求 請求項の数 2 (全7頁)

⑭ 発明の名称 光脱毛装置

⑯ 特 願 平1-200296

⑰ 出 願 平1(1989)8月3日

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## 明 細 書

## 1. 発明の名称

## 光 脱 毛 装 置

## 2. 特許請求の範囲

1. 赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電気的に制御する電気制御部とを備えた光脱毛装置において、

電気制御部には照射プローブの照射の実行と休止を交互に連続して行い、照射期間と休止期間の間隔を互いに独立して可変できる手段が装備してあることを特徴とする光脱毛装置。

2. 赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電気的に制御する電気制御部とを備えた光脱毛装置において、

照射プローブを保持し、横方向の移動を容易にするプローブ・キャリアが具備しており、このプローブ・キャリアには移動距離を検出する検出器が装備しており、電気制御部にはこの検

出器の出力信号から対象物に出射している照射時間を算定して所望照射時間の範囲内にあるかを判定する電気回路が配設してあることを特徴とする光脱毛装置。

## 3. 発明の詳細な説明

## 〔産業上の利用分野〕

この発明は、光脱毛装置、より詳しくは光を用いて皮脂腺と毛嚢内の毛の因子を乾固させ、永久脱毛を助長するため自動的に使用できる永久光脱毛装置に関する。

## 〔従来の技術〕

上に述べた種類に属する光脱毛装置は、特願平1-12459号公報により公知である。この公報に開示された光脱毛装置を利用する場合、照射光の光源としてそれぞれ赤色と青色の可視光領域に主強度を有する二種の発光光源を利用している。最初の予備加熱（プレヒーティング）で、比較的弱い強度の赤色光を脱毛すべき個所全体にまんべんなく照射する。次いで、比較的強い強度の赤色光で前記脱毛個所を照射して、皮脂腺開口部にある



毛の因子を乾固させる。その後、比較的強い青色光を照射して皮脂腺と毛嚢内の毛の因子を乾固させる。この状態にした後、脱毛ワックスにより照射箇所にある毛を脱毛する。その後、脱毛処理後によって開いた毛穴から毛の成長と発育を抑制するために使用する蛋白質分解酵素を擦り込む。この蛋白質分解酵素の働きを更に活性化させるため、比較的弱い赤色光を再び脱毛箇所に照射する（フラッシング）。

上記特願平 1-12459 号公報に開示した装置を使用する際、照射の開始はこの脱毛装置本体外に装備し、本体と電気導線を介して電気接続されているスイッチ、例えば足踏スイッチ又は照射プローブに付属させてあるマイクロスイッチを用いている。周知のように、脱毛したい箇所は、例えば脇の下のような狭い局所的な箇所の場合もあるが、総じて広い面積におよぶ箇所、例えば足の膝から下全部であったり、あるいは背中全体であったりする。照射プローブの照射領域の大きさは、例えばハロゲン・タングステン白熱灯による赤色

の比較的強い照射の場合、直径が約 5 mm φ で、キセノン・ランプによる青色の比較的強い強度の光では約 10 mm φ である。それ故、上に述べた広い面積をこの様に狭い照射範囲を有する照射プローブで処理するには、照射位置を百回またはそれ以上の回数も移動させて照射する必要がある。この困難を低減させるには、光源の強度を上げて照射面積を広くすることも考えられる。しかしながら、この処置では装置自体をいたずらに大型化し、価格の大幅な上昇と保守時の経費が嵩むことになる。それどころか、一回の照射で皮膚に加わる負担が大きく、装置に万一の故障があり、強力な照射光が所定時間よりも長く皮膚に照射されれば、身体に対して非常な危険が加わる恐れがある。

その外、前記特願平 1-12459 号公報で開示した実施例では、照射開始を上記の外部スイッチで行い、照射終了を本体に内蔵したタイマーで自動的に決めている。この方式の場合、上に述べた百回またはそれ以上の回数でこの外部スイッチを操作しながら、照射プローブの移動と位置設定

を行う必要がある。脱毛処理を実際に行う人は、通常専業としている使用者であるが、一日に一人だけでなく、数人又は十数人の人に対して脱毛を行う。それ故、この外部スイッチを操作するのみで既に足又は指先に疲労を覚える。しかも、照射プローブの移動と設定にも、使用者はこのプローブを横に移動させる運動と皮膚に押し付ける運動とが要求されるので筋肉疲労が生じる。このことは、使用回数が増加すると、使用者に疲労が重なり職業病にもなりうることを意味する。

更に、上に試算した百回以上の移動と設定には多から少なかれ何らかの時間を要し、一回の移動に要する時間がたとえ比較的少なくても、これ等の移動全体で積算すると、意外に長時間を要し、実効使用時間を非常に浪費することになる。

〔発明が解決しようとする問題点〕

上に述べた従来の装置に見られる難点を鑑み、この発明の課題は、照射を開始させる操作を手動でなく、自動化して実効使用時間を有効に活用し、同時に照射時に生じる疲労を大幅に軽減する光脱

毛装置を提供することにある。

〔問題点を解決するための手段〕

上記の課題は、この発明により、赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電氣的に制御する電気制御部とを備えた光脱毛装置であって、電気制御部には照射プローブの照射の実行と休止を交互に連続して行い、照射期間と休止期間の間隔を互いに独立して可変できる手段が装備してある光脱毛装置、又は赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電氣的に制御する電気制御部とを備えた光脱毛装置であって、照射プローブを保持し、横方向の移動を容易にするプローブ・キャリアが具備してあり、このプローブ・キャリアには移動距離を検出する検出器が装備してあり、電気制御部にはこの検出器の出力信号から対象物に出射している照射時間を算定して所望照射時間の範囲内にあるかを判定する電気回路が配設してあることを特

微とする光脱毛装置によって解決されている。

#### 〔作用〕

上記の構成により下記の作用が得られる。即ち、いずれの光の照射開始も装置内で自動的に決定される。また、照射プローブを皮膚に押し付けて移動させることができる。そして移動速度に見合った照射が自動的に行われ、同一箇所を許容時間以上照明することがない。

#### 〔実施例〕

この発明による光脱毛装置の実施例を以下に図面に基づき詳しく説明する。

第 1 図には、この発明による光脱毛装置の機能ブロック図が示してある。既に特願平 1-12459 号公報で開示したように、照射プローブと発光光源との間に使用する連結部には種々の方式がある。説明の理解を助けるため、照射プローブ 5 は一個で、連結部 6 も一本で、赤色発光光源 3 と青色発光光源 4 から発する各光は、本体 1 内部に配設してある混合器 7 を経由して連結部 6 に導入される方式のものを使用する。もちろん、その他

には赤色発光光源 (R) を使用するか、あるいは青色発光光源 (B) を使用するかを選択する切換スイッチ  $SW_s$  が装備してある。なお、この発明自体に直接関係のない、例えば主電源開閉器、表示ランプ等のそれ自体公知でどの電気装置にも通常使用される機能部品は説明を複雑にするので図示しない。

この実施例に示す脱毛装置の動作は、第 2 図に示す発光光源 3 又は 4 をトリガーするためのトリガー信号波形から理解できるように、照射プローブ 5 の照射期間が  $T_A$  であり、休止期間が  $T_B$  であるように設定してある。光照射は両期間  $T_A$ ,  $T_B$  が交互に切り替わるこのトリガー信号によって制御される。このようなスイッチング波形を発生させる回路は、当業者であれば容易に推察できるように、自走マルチバイブレータ (双安定マルチバイブレータ) を用いて極めて容易に構成できる。その外、市販のタイマーないしはシーケンス・コントロール・ユニットでも形成できる。その際、照射期間と休止期間の時定数は、それぞれに対応す

る方式でも以下の説明から容易にこの発明の構成を適用できることは明らかである (詳しくは、特願平 1-12459 号公報参照)。

この発明の第一の実施例では、第 1 図の光脱毛装置の本体 1 中に装備してある発光光源の電気制御部 2 に次の処置が講じてある。つまり、この制御部 2 は三個に分割して、それぞれ赤色発光光源制御部 2 A、青色発光光源制御部 2 B 及び共通制御部 2 C から構成されている。本体 1 中にある操作を設定する主要部は、それぞれ赤色発光光源制御部 2 A に、赤色発光光源を自動 (A) 又は手動 (M) で操作するための切換スイッチ  $SW_R$ 、赤色光の強度設定部  $V_{IR}$ 、赤色光の照射を継続する照射期間設定部  $V_{TRI}$ 、赤色光の照射を中断している休止期間設定部  $V_{TRI}$  が、また青色発光光源制御部 2 B に、青色発光光源を自動 (A) 又は手動 (M) で制御するための切換スイッチ  $SW_B$ 、青色光の強度設定部  $V_{IB}$ 、青色光の照射を継続する照射期間設定部  $V_{TRI}$ 、青色光の照射を中断している休止期間設定部  $V_{TRI}$  が配設してある。更に、共通制御部 2 C

る RC 回路素子によって決まるのもで、第 1 図ではこの回路素子を可変抵抗にして暗示的に示してある (もちろん、この設定は可変抵抗でなく、可変コンデンサで実現できることは言うまでもない)。即ち、赤色を例にとれば、照射期間  $T_A$  は照射期間設定部  $V_{TRI}$  によって、また休止期間  $T_B$  は休止期間設定部  $V_{TRI}$  によって設定される。

上の説明は、赤色発光光源の場合に対して説明したが、同様な設定は青色発光光源の場合に対しても当てはまる。

第 1 図の構成でこの発明による光脱毛を実際に行うには、各色の発光光源の使用条件の設定 (切換スイッチ  $SW_R$ ,  $SW_B$ , 強度設定部  $V_{IR}$ ,  $V_{IB}$ , 照射期間設定部  $V_{TRI}$ ,  $V_{TRI}$ , 休止期間設定部  $V_{TRI}$ ,  $V_{TRI}$  等) は既に完了していると仮定すると、赤色光を照射する場合、先ず脱着可能な光導体ケーブル・コネクタ 8 に赤色光照射プローブ 5 を装着して、使用光源の選定をスイッチ  $SW_s$  によって接点位置 R に切り換える。また、青色の場合にはスイッチ  $SW_s$  を接点位置 B に切り換える。赤色

光のプレヒーティング及びフラッシングでは、光照射強度を低くして照射面積を広げて照射するので照射プローブ5の交換、又はプローブ先端にアダプターを付ける必要がある(特願平1-12459号公報参照)。赤色又は青色発光源は、常時第2図のシーケンスに従って発光、休止を行っている。それ故、使用者は照射プローブと休止期間T<sub>0</sub>の間中に皮膚の所望箇所に移動させ、その上に押圧固定する照明期間T<sub>1</sub>の間照射する。

第2図の照射条件では、休止期間を出来る限り短くして、照射プローブをこの間隙の照射箇所に移動させて、有効作業時間を短縮する必要がある。それには、照射プローブの移動を絶えず素早く行う訓練が使用者に対して必要である。

この照射プローブの移動と照射期間との関係を使用者の訓練を待たずに実行できる装置の照射プローブ部分を第3a図と第3b図に示す。第3a図の断面図には、第1図の照射プローブ5に相当する光導体ケーブル11の先端部分16が、非導電性材料のゴム又はプラスチック製のプローブ・

キャリア10の対応する穴に挿入してある。その場合、外部被覆12の段が対応するキャリアー10の表面に当接するまで挿入してある。このキャリア10の窪み18には、中心を貫通する回転軸22を具備するロール20がキャリア10中に埋め込んである軸受(図示せず)に回転可能に支承されている(第3b図も参照)。このロール20の表面近傍に多数の、例えばフェライトあるいはサマリウム・コバルト合金等の永久磁石片24が等間隔で埋め込んである。これ等の磁石片24は、その着磁方向を交互に逆転させて配列してある。他方、窪み18の底の部分には磁場検出用センサ30が埋め込んである。このセンサの出力信号は、給電・出力信号線32を経由してコネクタソケット35のソケットピン34を挿入できるリセブタクル片33に通じている。出力信号はこのピン34から更に導線36を経由して本体1の信号処理回路2に導入される。

プローブ・キャリア10は、この断面図から理解できるように、皮膚38に密着させたまま移動

できるので、従来の照射プローブのように移動の際皮膚から一旦離して、所望の脱毛箇所に再び押し付ける動作は不要である。そのため、無駄な力を使わずにプローブ先端16を移動させることができる。更に、重要なこのキャリア10の特徴として、キャリア10の動きに伴い回転するロール20中の永久磁石片24が、磁場検出用センサ30に磁場変化を与えるので、出力信号も変化させる。このようにして、ロール20の移動距離が検出される。

先に説明した第一実施例では、特に図示しなかったが、照射プローブをここに示したロール付きキャリアに装着し、しかも位置検出部を取り付けておかない場合でも、その作業上の有用性は上に述べた理由により明らかである。

第4図には、この出力信号を利用してプローブ・キャリア10の適正な移動速度及び過度の光照射を防止させる照度検出演算部100の概要が示してある。

磁場検出用センサ30を、例えばホール素子M

Sとする。この素子MSの両端に基準電位を印加し、直交方向の端部から周知のようにホール電位を測定すると素子MSの受けている磁場を初段増幅器A<sub>1</sub>によって知ることができる。得られた出力信号は初段増幅器A<sub>1</sub>の出力端側に模式的に示した波形であるが、この信号を波形整形回路T<sub>1</sub>に導入して、正又は負の信号レベル側に飛び出す方形波に整形して正の方形波からトリガーパルスを形成するトリガー段LMTと、負の方形波からトリガーパルスを形成するトリガー段INVに導入する。両トリガーパルスは、それぞれフリップ・フロップFFのセット及びリセット端子S、Rに導入される。フリップ・フロップFFの出力信号Qは、計数器CNTのセット端S'に導入される。他方、この計数器CNTには、クロック発生器CLKのタイミングパルスを分周器DVで適当な周期のクロックパルスに落として前記計数器CNTに導入する。計数器CNTのリセットは、フリップ・フロップのQ出力によって各対の磁極片毎に行われる。

計数器 C N T の計数出力は、隣合った永久磁石片 24 がホール素子 M S を通過した時間を表すもので、この磁石間の距離は既知であるから、ロール 20 の回転速度も算出できる。従って、この計数出力を更にデジタルウインド比較器 L と U に導入して、ここでロール 20 の回転速度が所定の回転速度内、つまり最低許容速度と望ましい最高速度の間にあるか否かを判定できる。最低許容速度と望ましい最高速度に対応するデジタルしきい値は、付属キーボード C B D から入力されて、符号化回路 E N C で符号化処理され、それぞれ信号導線  $\alpha$  と  $\gamma$  を経由して比較器 L と U に導入されている。ロール 20 の回転速度が望ましい最高しきい値を越えると、比較器 U の出力 O U T 2 は、例えば「H」レベルに変わり、越えなければ「L」レベルを維持する。他方、ロール 20 の回転速度が最低許容しきい値以下であれば、比較器 L の出力は「L」レベルを維持しているが、このしきい値以上では比較器 L の出力は、ロール 20 の回転速度が遅すぎると言う警報信号に相当する「H」レ

ベルに変わる。そして、この出力はモノステーブルマルチバイブレータ M S T に導入されて、第 2 図に示した休止時間  $T_0$  に相当する時間の後、再び「L」レベルに戻る。 $T_0$  に相当する時間の指定はキーボード C B D から符号化回路 E N C と導線  $\beta$  を経由してモノステーブルマルチバイブレータ M S T に導入されている。そこから出力 O U T 1 として外部に出力される。

出力 O U T 1 が「H」レベルになることは、照射時間が許容範囲以上に長いことを意味し、照射発光光源を休止させる指令を照度検出演算部 100 からこの発光光源の駆動回路（例えば、第 1 図の発光光源 3 又は 4）に出力するように設計する。同時に、この状態を本体 1 の表示部の、例えば L E D に表示したり、あるいは音声で警報するのも効果的である。また出力 O U T 2 が「H」レベルであれば、照射時間が短いことを意味し、照射が不十分である。その場合は手動で行っているグローブ・キャリヤ 10 の移動速度を遅くする必要がある。もちろん、この状況も表示ランプ及び／又は

音声警報を表示警告すると効果的である。

照射グローブの有効照射面の直径（又は一方の辺の長さ）を D とすると、グローブの移動速度  $v$  は、第 2 図に規定した適正照射期間  $T_A$  に対して次の関係、

$$v = D / T_A$$

を満たす必要がある。この速度は、第二実施例の照射グローブ・キャリヤの適正移動時の移動速度を規定するもので、その速度の上限と下限の二パラメータは第 1 図の照射期間設定部  $V_{TR1}$ ,  $V_{TR2}$  と休止期間設定部  $V_{TR1}$ ,  $V_{TR2}$  に相当する。

上記の第二実施例では、ロール 20 の回転速度を磁気検知素子で検出しているが、この技術思想を光電的に実現することも可能である。この場合、検出器 30 は発光素子として発光ダイオード、受光素子としてフォトランジスタによって構成され、磁石片 22 は単に光の反射材料で作製される。更に、照度検出演算部 100 は、ほぼ類似な回路方式で形成することができる。

その外、ここに示した二つの実施例はこの発明の根底をなす設計思想を逸脱することなく、種々の様式に変形することができるのは明白である。例えば、例えば第 3 a, b 図のロール 20 をキャリヤ 10 の中に一個だけでなく、二個又はそれ以上配設することもできる。また、デジタル入力方式である第 4 図のキーボード C B D を、第 1 図の照射光強度設定部、照射時間設定部のような可変抵抗のようなアナログ入力方式もそれに応じた照度検出演算部 100 内の回路を変更すれば可能である。

#### 〔発明の効果〕

この発明による光脱毛装置の著しい利点は、

- (1) 照射開始を外部操作によって行わず、自動的に装置内で決定されるので、長時間の使用に対して疲れが生じない。
- (2) この発明の第二実施例の構成によれば、照射グローブを皮膚から離して移動させるのではなく、常時押し付けて実行できるので、長時間の使用に対して疲れが生じない。

- (3) 移動速度に見合った照射を自動的に保証でき、また同一箇所を許容時間以上照明することがないので、安全に使用できる。
- (4) 休止期間を短縮できる、ないしは休止期間がないので、脱毛処理能力が著しく上昇することにある。

#### 4. 図面の簡単な説明

第1図は、この発明による第一実施例としての光脱毛装置のブロック図である。

第2図は、第1図の光脱毛装置で使用する自動照明駆動シーケンスの出力信号の波形図である。

第3a図と第3b図は、照射プローブと移動速度検出器を装着したプローブ・キャリアの断面図と下から眺めた平面図である。

第4図、第3a、b図のキャリアの移動速度を検出した出力信号の演算処理部を示すブロック回路図である。

図中引用記号：

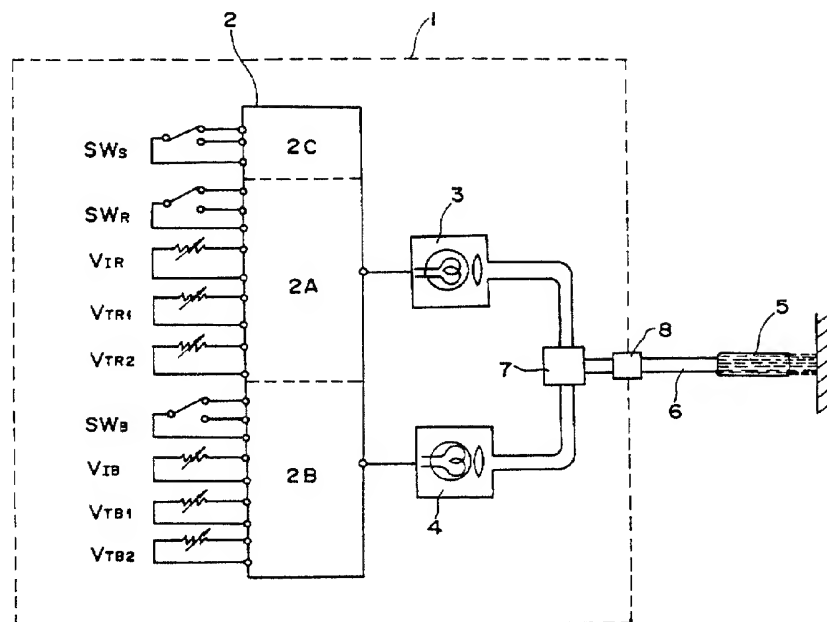
- 1・・・本体、  
2・・・電気制御部、

- 3・・・赤色発光源、  
4・・・青色発光源、  
5・・・プローブ、  
10・・・プローブ・キャリア、  
20・・・ロール、  
24・・・磁石片、  
30・・・磁気検出器、  
100・・・照度検出演算部。

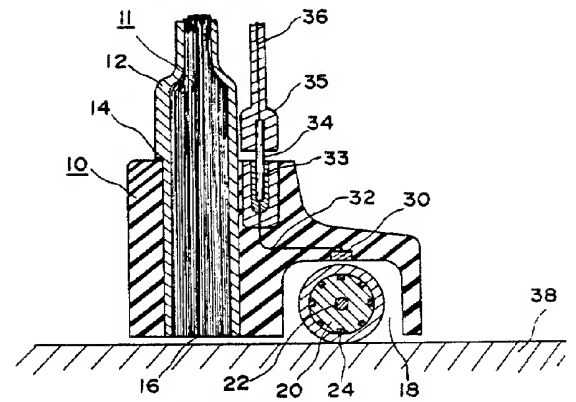
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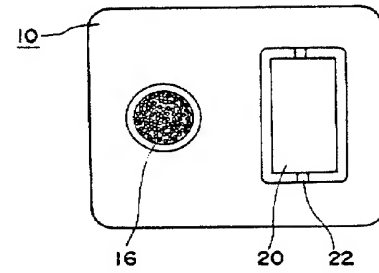
第1図



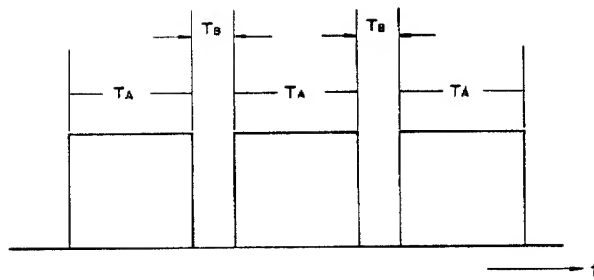
第 3a 図



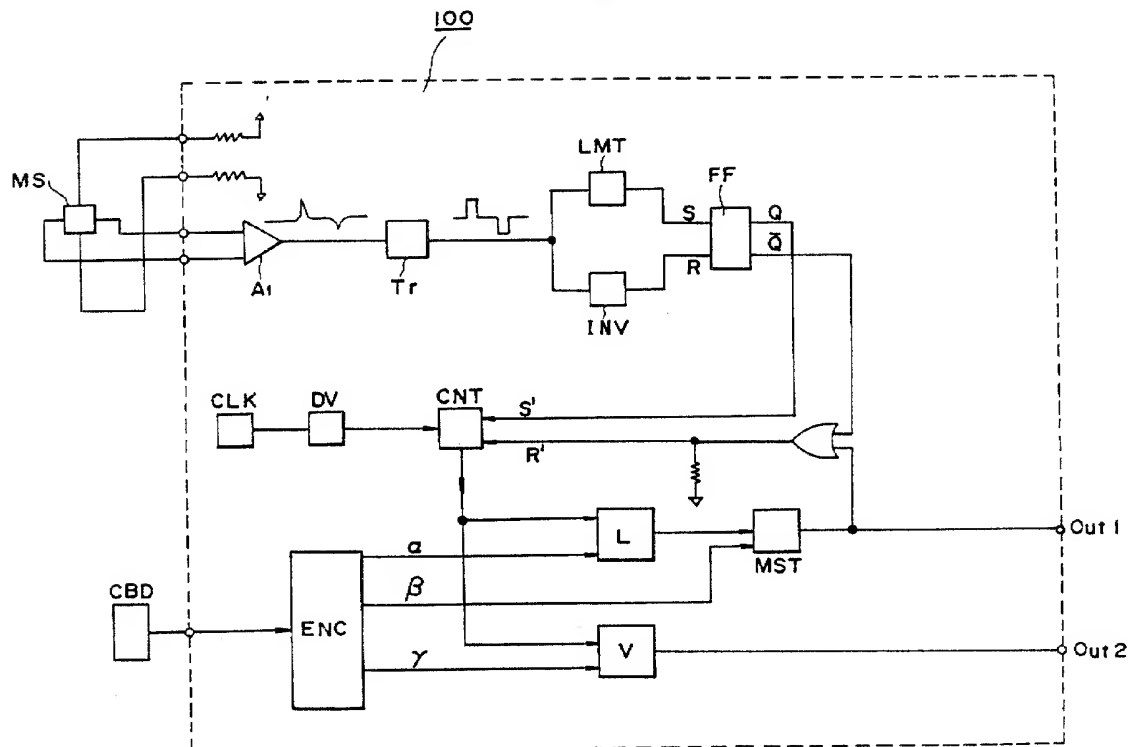
第 3b 図








第 2 図



第 4 図

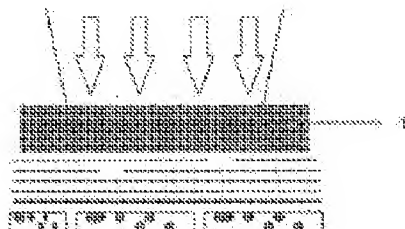


**USE OF COMPOUND CONTAINING CHROMOPHORE TO BE APPLIED TO SKIN PRIOR TO LASER TREATMENT****Publication number:** JP10165410 (A)**Publication date:** 1998-06-23**Inventor(s):** MORDON SERGE; SUMIAN CHRYSLAIN; BUFFARD KARINE;  
PITRE FRANCK; BOUCLIER MARTINE**Applicant(s):** CIRD GALDERMA**Classification:****- international:** **A61B18/20; A61N5/06; A61N5/067; A61B18/20; A61N5/06;**  
A61B18/20; (IPC1-7): A61B17/36; A61N5/06**- European:** A61N5/06C8**Application number:** JP19970334697 19971204**Priority number(s):** FR19960014954 19961205**Also published as:** EP0846477 (A1) US6086580 (A) FR2756741 (A1) CA2222027 (A1) CA2222027 (C)

more &gt;&gt;

**Abstract of JP 10165410 (A)**

**PROBLEM TO BE SOLVED:** To provide a compound containing chromophore used to smooth a skin and cut a tissue using a laser which emits light in a visible spectrum area or infrared ray spectrum area. **SOLUTION:** By applying a compound containing chromophore to a skin surface, a light absorption ability is obtained which prevents a laser energy transmitted into the skin from causing unwanted irreversible damage to tissue or cells, and a light energy can be converted into a thermal energy locally at the compound applied.

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(19)日本国特許庁 (J P)

(12) 公 開 特 許 公 報 (A)

(11)特許出願公開番号

特開平10-165410

(43)公開日 平成10年(1998)6月23日

(51)Int.Cl. <sup>6</sup>	識別記号	F I
A 6 1 B 17/36	3 5 0	A 6 1 B 17/36 3 5 0
A 6 1 N 5/06		A 6 1 N 5/06 E

審査請求 有 請求項の数25 O L (全 9 頁)

(21)出願番号 特願平9-334697

(22)出願日 平成9年(1997)12月4日

(31)優先権主張番号 9 6 1 4 9 5 4

(32)優先日 1996年12月5日

(33)優先権主張国 フランス (F R)

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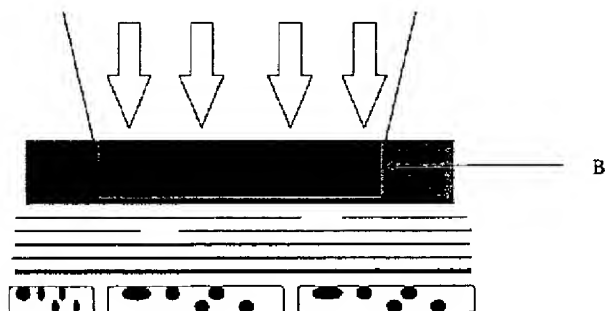
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(54)【発明の名称】 レーザー処理前に皮膚に塗布する組成物における発色団の使用

(57)【要約】

【課題】 可視スペクトル領域または赤外線スペクトルで発光するレーザーを用いて皮膚を滑らかにし、及び組織切除するための発色団を有する組成物を提供する。

【解決手段】 発色団を有する組成物を皮膚表面に塗布することにより、皮膚中に透過したレーザー光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有し、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にする。





## 【特許請求の範囲】

【請求項1】 1つ以上の発色団を含有する組成物を用いて、皮膚表面で光エネルギーを熱エネルギーに変換する方法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にすることを特徴とする、レーザー放射線の光エネルギーを熱エネルギーに変換する方法。

【請求項2】 レーザー放射線を皮膚表面に照射する前に同皮膚表面に局所的に塗布することを目的とした組成物の製造における1つ以上の発色団の使用であって、レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換を、塗布された組成物中で局所的に達成することを可能にし、この熱エネルギーにより、上記皮膚表面の下で皮膚部分の組織切除を達成することを可能にすることを特徴とする使用。

【請求項3】 上記組成物および同組成物の塗布厚が、皮膚中に透過した光エネルギーが好ましくない不可逆的組織損傷あるいは細胞損傷を生じさせるレーザーの発光波長において吸光度を有することを特徴とする請求項2に記載の使用。

【請求項4】 組織切除目的が、皮膚の非美学的特性、たとえばシワ、スジ、イボ、萎縮した傷跡および／または肥大化した傷跡などの切除であることを特徴とする請求項2あるいは3のいずれか1項に記載の使用。

【請求項5】 組織切除目的が、医学的処置の補完法であって、鼻咽喉腫瘍(rhinophyma)、過角化症、皮膚過増殖、乾癬斑、皮膚癌、光線性角化症、ケロイドなどの皮膚疾患を治療することであることを特徴とする請求項2または3のいずれか1項に記載の使用。

【請求項6】 組織切除目的が、化粧または医薬活性薬剤、特に皮膚科学的活性薬剤の透過性を増大させることであることを特徴とする請求項2または3のいずれか1項に記載の使用。

【請求項7】 熱エネルギーが角質層の組織および表皮の切除のみを達成することを可能にすることを特徴とする請求項2～6のいずれか1項に記載の使用。

【請求項8】 熱効果が放射照度約 $10^8$  W/cm<sup>2</sup>未満のレーザーによって得られ、好ましくは放射照度約 $10^7$  W/cm<sup>2</sup>以下のレーザーによって得られることを特徴とする請求項2～7のいずれか1項に記載の使用。

【請求項9】 熱効果が、放射照度が $0.5$  W/cm<sup>2</sup>以上、好ましくは $10$  W/cm<sup>2</sup>以上、さらに好ましくは $100$  W/cm<sup>2</sup>以上のレーザーにより得られることを特徴とする請求項

2～8のいずれか1項に記載の使用。

【請求項10】 発色団が、カーボンブラック、グラファイト、鉄黒、ベンガラなどの無機発色団およびメラニン、インドシアニングリーン、染料、またはその他の問題にする波長において、十分な光吸収性を有する不活性化学物質などの有機発色団から選ばれることを特徴とする請求項2～9のいずれか1項に記載の使用。

【請求項11】 発色団が無機発色団であることを特徴とする請求項10記載の使用。

【請求項12】 発色団および／または同発色団を含有する組成物が、発色団が皮膚を透過しないように選択および／または調合したものであることを特徴とする請求項2～11のいずれか1項に記載の使用。

【請求項13】 レーザー光線を照射する前に、組成物、特に皮膜形成性組成物を塗布し、その際、同組成物が、1つ以上の発色団を含有する同組成物上で、用いた波長において光を吸収しないことを特徴とする請求項2～12のいずれか1項に記載の使用。

【請求項14】 可視光線スペクトル領域で発光するレーザー、特に、パルス化色素レーザー(585nm)、ルビーレーザー(694nm)、二重化Nd:YAGレーザー(532nm)などを用いることを特徴とする請求項2～13のいずれか1項に記載の使用。

【請求項15】 赤外線スペクトル領域で発光するレーザー、特に、CO<sub>2</sub>(10.6μm)、Er:YAG(2.94μm)、Ho:YAG(2.12μm)、Nd:YAG(1.06μm)などのレーザーを用いたことを特徴とする請求項2～13項のいずれかに記載の使用。

【請求項16】 特にシワやスジを減少させることを目的とした美容処置法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成することを可能とし、かつ同熱エネルギーにより、上記皮膚表面の下で皮膚部分の組織切除を可能にすることを特徴とする美容処置法。

【請求項17】 熱エネルギーにより、角質層の組織および表皮切除を達成することを可能にすることを特徴とする請求項16記載の方法。

【請求項18】 熱効果が放射照度約 $10^8$  W/cm<sup>2</sup>未満のレーザーにより得られ、好ましくは放射照度約 $10^7$  W/cm<sup>2</sup>以下のレーザーにより得られることを特徴とする請求項1または16あるいは17のいずれか1項に記載の方法。

【請求項19】 熱効果が、放射照度 $0.5$  W/cm<sup>2</sup>以上、

好ましくは $10\text{W}/\text{cm}^2$ 以上、さらに好ましくは $100\text{W}/\text{cm}^2$ 以上のレーザーにより得られることを特徴とする請求項1または16～18のいずれか1項に記載の方法。

【請求項20】 発色団が、カーボンブラック、グラファイト、鉄黒、ベンガラなどの無機発色団およびメラニン、インドシアニングリーン、染料、その他問題とする波長において、十分な光吸収性を有する不活性化学物質などの有機発色団から選ばれることを特徴とする請求項1または16～19のいずれか1項に記載の方法。

【請求項21】 発色団が無機発色団であることを特徴とする請求項20記載の方法。

【請求項22】 発色団および／または同発色団を含有する組成物が、同発色団が皮膚を透過しないように選択および／または調合されたことを特徴とする請求項1または16～21のいずれか1項に記載の方法。

【請求項23】 レーザー光線を照射する前に、組成物、特に皮膜形成性組成物を塗布し、その際、同組成物が、1つ以上の発色団を含有する同組成物上で用いた波長において光を吸収しないことを特徴とする請求項1または16～22のいずれか1項に記載の方法。

【請求項24】 可視光線スペクトル領域で発光するレーザー、特にパルス化色素レーザー(585nm)、ルビーレーザー(694nm)、二重化Nd:YAGレーザー(532nm)などを用いることを特徴とする請求項1または16～23項のいずれか1項に記載の使用。

【請求項25】 赤外線スペクトル領域で発光するレーザー、特に、 $\text{CO}_2$ ( $10.6\mu\text{m}$ )、Er:YAG( $2.94\mu\text{m}$ )、Ho:YAG( $2.12\mu\text{m}$ )、Nd:YAG( $1.06\mu\text{m}$ )などのレーザーを用いたことを特徴とする請求項1または16～23のいずれか1項に記載の方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明はレーザー処理の前に皮膚に塗布する組成物における発色団の使用に関連する。レーザー処理時に生じた熱効果は、主として組織の切除を生じさせることを目的としている。

【0002】

【従来の技術及び発明が解決しようとする課題】レーザーの放射光と生体組織との間の本質的な相互影響は複雑であり、多数の要因に依存する。現在、皮膚の病理学、皮膚疾患および非美容的特性において、特定タイプのレーザーが必要である。その選択は、本質的に何を目的としているか、そしてどのような効果を生じさせるかによる。

【0003】特に、レーザーの力による皮膚のイニシャル層(真皮の深さまで延びる可能性がある)の切除、または皮膚の平滑化は、赤外線スペクトル領域にあり、主に水に吸収される波長を有するレーザー光線のみを用いて実行される。しかし、皮膚における水の分布は、問題の部位、処理を受ける個々の人の皮膚のタイプおよび年齢

などによって異なる。細胞内での水を標的とした皮膚のキメのレーザー処理は、個人によって再現性がないことは明らかである。赤外線スペクトルで放射し、細胞内での水を標的とするレーザーの例としては、 $\text{CO}_2$ ( $10.6\mu\text{m}$ )、Er:YAG( $2.94\mu\text{m}$ )、Ho:YAG( $2.12\mu\text{m}$ )が含まれるレーザーがある。

【0004】可視光スペクトルまたは近赤外線(波長400nm～1000nm)領域で放射するレーザーは、皮膚に対して深い貫通力を有し、主として色素タイプの生体管の障害の処置に用いられるが、皮膚の平滑化に用いることはできない。可視光スペクトルで発光するレーザー光の例としては、管の障害の処置用のパルス化有色レーザー光(585nm)およびそれと色素障害処理用の二重化Nd:YAGレーザー光が挙げられる。

【0005】光の照射による皮膚の臨牀的、組織学的応答は、用いたレーザー光のタイプと波長により大きく異なる。標的部位には多数の効果が生じる可能性があり、これらの効果は、発色団の性質(与えられた波長の吸光係数、構造、化学組成、等)、単位表面積あたりのエネルギー(または光束)および単位表面積あたりの強さ(照度)に直接依存する。生体組織に対する放射線の相互作用を研究することにより、現われる数種のメカニズムを識別することが可能となる。皮膚科学の分野では、レーザーの使用は、主として2種類のメカニズム、光エネルギーが熱エネルギーに変換される熱効果と、光が衝撃波を生じさせる機械的效果とに基づいて行われる。

【0006】熱効果は、生体組織がレーザー光線によってもたらされた光エネルギーを吸収し、その光エネルギーが熱エネルギー形態で局所的に散逸するによる。与えられた波長によって、生体組織が加熱される度合いは、光束および放射照度に依存する。加熱の強さにより、生体組織を構成する細胞の凝集、炭化、切除などが観察される。レーザーの熱作用は、組織の加熱量及びその時間の長さにより、主として次の3つの効果に分類することができる。

【0007】— 高熱は、適度な温度上昇であり、組織は数分の間に $41\sim 44^\circ\text{C}$ に加熱される。この作用により、膜の消失及び酵素の変性により細胞がダメージを受ける。

— 凝集は、壊死の状態に対応し、直ちに生体組織が破壊されることはない。1秒間の時間スケールで、組織が達する温度は、 $50\sim 100^\circ\text{C}$ である。この作用により、タンパク質およびコラーゲンの変性の結果、組織が収縮し、脱水が起こる。壊死は不可逆的であるが、しかし直ちに物質を失うことはない。

— 切除(ablation)は、物質を失うことに相当する。生体組織の種々の成分が蒸発によって除去される。到達温度は、比較的短時間(1/10秒のスケール)で $100\sim 1000^\circ\text{C}$ となる。 $100\sim 300^\circ\text{C}$ で組織は、液胞破壊による爆発的蒸発により除去される。

【0008】照射域と健康域の間の熱遷移は徐々に起こり、組織学的検討を行うことにより、照射域に最も近い域から最も離れた域へと順に、炭化域または組織切除域(150℃で細胞間炭素が脱離)、凝集域および高温域の3つの区域をわけることができる。

【0009】熱エネルギーが生体組織内で散逸する場合、隣接する組織に熱的損傷が起こるのを抑制するために、レーザー照射時間を熱緩和時間と呼ばれる時間に合わせることが重要であると思われる。物理的観点から考えると、熱緩和時間は、生体組織が過剰温度のうち、初期温度を基準として50%減少させるのに必要な時間である。レーザー照射持続時間がこの緩和時間よりも小さいと、熱は組織内部に拡散することができず、照射された空間部分に閉じ込められたままの状態となる。さらに、この緩和時間内において標的部位に蓄積されるエネルギーが多くなって100℃をはるかに越えるレベルまで温度を上昇させたならば、媒質の局所的蒸発を生じさせる。まだ冷却状態にある組織内部において蒸気泡が膨張すると、振幅の小さな熱弾性波を生じさせる。この選択的光熱分解過程は、たとえば皮膚の血管形成異常の治療に用いられる。すなわち、赤血球がパルスを吸収して爆発、蒸発し、この蒸気が急速に膨張することにより血管が破壊され、血管外溢出が起こる。この技術を表面に用いると、標的組織を局所的に切除することを可能にする。

【0010】さらに、種々の生体組織の吸収スペクトルを研究した結果、放射線の透過する深さは波長に依存することが分かった。したがって、エネルギーの熱形態での散逸は相互作用空間部分内で起こり、この相互作用空間部分は本質的に、照射線の透過深さ(照射域)、影響を受ける組織の拡散係数および熱伝導係数、そして標的部分の局所血管新生と、同標的部分が蓄熱を保持もしくは失う能力に依存する。

【0011】上述のように、熱効果は一般に、約 $10^8 \text{ W/cm}^2$ よりも小さな放射照度により得られ、これは、約 $10^{-5} \text{ s}$ 以上の発光時間に相当する。

【0012】機械的効果は、多量の光エネルギーが十分に小さな領域に十分短い時間で濃縮され、媒質の光学破壊が起こる可能性に基づく。この光学破壊が起こる結果、放射照度が $10^8 \text{ W/cm}^2$ 以上の大きな照射により、プラズマ、すなわち広範囲にわたりイオン化された気体が形成される( $10^8 \text{ W/cm}^2$ という放射照度は $10^{-7} \text{ s}$ 以下の発光時間に相当する。すなわち、熱効果の場合よりも100倍短い持続時間に相当する)。このプラズマの形成には、衝撃波の発生、空洞現象、ジェット形成などが伴う。イオン化媒質(プラズマ)と外部媒質の境界には圧力勾配が生じ、それにより衝撃波が形成され、この衝撃波は隣接組織へと伝達される。この現象(パルス後50~150 nsの間)に続いて、空洞が現れ、すなわち泡が形成され、この空洞は、数百 $\mu\text{s}$ の間に膨張と崩壊(泡がそこで消失)の振動過程による。これらの崩壊の間に、泡中の

圧力が相当に増大するため、新しい衝撃波が放出される。

【0013】最後に、泡が固体壁の近く(例、骨の付近)に発生した場合、それぞれの崩壊現象によりジェットが形成される可能性がある。この場合、ジェットは固体壁の表面損傷(固体の局所侵食)の原因となることがある。

【0014】したがって、米国特許第5,423,803号は、赤外線スペクトル領域(Nd:YAG, 1064nm;  $\text{CO}_2$ , 10.6 $\mu\text{m}$ )で発光し、50ns以下の発光時間を有するレーザーを用いて、人間の皮膚から角質層の一部を切除する方法について記述している。レーザー照射前、発色団を含有する組成物を処置対象の皮膚に塗布する。超音波かレーザーのいずれかを用いて、これらの発色団を角質層の細胞内空間の中に入れる。続いてこの皮膚の処理部分に、発色団をイオン化する(光学破壊後)のに十分なエネルギーをもったレーザー光線を照射する。上述のように、発色団がイオン化される結果、角質層の最初の3つの細胞レベルの切除の原因となる衝撃波(機械的効果)が形成される。この効果は衝撃波の放出に基づいているため、処理しようとする部分に隣接する組織に好ましくない不可逆的損傷を引き起こすという欠点がある。さらには、この処理の有効性は、発色団の角質層中への透過により空間的、質的に制限される。

【0015】本発明の目的の一つは、可視スペクトル領域で発光するレーザーを用いて皮膚を滑らかにすることを可能にすることである。

【0016】本発明のもう一つの目的は、赤外線スペクトル領域で発光するレーザーを用いて皮膚を滑らかにする処理を再現性のあるものとするすることである。

【0017】もう一つの目的は、好ましくない不可逆的損傷の形成を回避する処理法を提供することにある。

【0018】

【課題を解決するための手段】これらの目的やその他の目的は本発明により達成される。本発明は、1つ以上の発色団を含有する組成物を用いて、皮膚表面において、レーザー放射線光エネルギーを熱エネルギーに変換する方法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記の皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にすることを特徴とする、レーザー放射線の光エネルギーを熱エネルギーに変換する方法に関連する。

【0019】特に、1回のレーザーショットの間に組成物中に生じる熱エネルギーは、皮膚内部の熱伝導によっ

て伝わり、局所的に温度を100℃以上に増大させ、組織切除を達成することが可能となる。

【0020】したがって、本発明はさらに、レーザー放射線を上記皮膚表面に照射する前に皮膚表面に局所的に塗布することを目的とした組成物の製造における1つ以上の発色団の使用であって、レーザーにより生じた照射により、塗布された組成物中において局所的な光エネルギーの熱エネルギーへの変換達成を可能にし、この熱エネルギーにより、上記皮膚表面の下にある皮膚の組織切除達成を可能にするような、発色団の利用にも関わる。

【0021】レーザーの発光波長に吸光度をもったこの組成物とその塗布厚は、皮膚中に透過する光エネルギーにより好ましくない不可逆的な組織損傷あるいは細胞損傷を生じさせないようなものであることが好ましい。

【0022】組織切除の後、より若々しい、および／または優美さに欠ける点の改善された新生の皮膚の形成が可能となり、このことは皮膚を滑らかにすることに相当する。さらに具体的にいうと、この方法によれば、皮膚の非美的特性、たとえばシワ、スジ、イボ、萎縮した傷跡および／または肥大化した傷跡などを除去することができる。さらに、この処理法は、例えば、鼻咽腫瘍(rhinophyma)、過角化症、皮膚過増殖、乾癬斑、皮膚癌、光線角化症、ケロイドなどの皮膚病状の治療のための医学的処理法そのもの、もしくはその補完法として使用することができる。

【0023】さらには、組織切除は、化粧品あるいは医薬品、特に皮膚科学的活性薬剤の浸透を増大させることを可能にする。この場合、照射後かつ新生皮膚の完全形成前に、1種類以上の活性薬剤を含有する化粧品または医薬品組成物が塗布される。活性薬剤の実例としては、局所および／または全身投与を目的とした医薬品として経皮的に使用される活性薬剤、特に、レチノイン酸、同酸誘導体(レチノイド類)、過酸化ベンゾイル、抗生物質、コルチコステロイド、抗菌剤、ビタミンD3、D2およびその誘導体が挙げられる。

【0024】本発明はさらに、美容的処置法、特にシワやスジを減少させる美容的処置法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にし、かつこの熱エネルギーにより、上記表面の下にある皮膚部分の組織切除を達成することを可能にすることを特徴とする美容的処置法に関連する。

【0025】熱効果は光エネルギーの熱エネルギーへの

変換に対応する上述のような効果である。したがって、この熱効果は一般に、放射照度がおおよそ $10^3 \text{ W/cm}^2$ よりも小さなレーザーにより得られ、この放射照度は、約 $10^{-5} \text{ s}$ 以上の発光時間に相当する。この効果は、好適には放射照度が約 $10^7 \text{ W/cm}^2$ 以下のレーザーにより達成される。

【0026】放射照度は、好ましくは $0.5 \text{ W/cm}^2$ 以上であり、より好ましくは $10 \text{ W/cm}^2$ 以上、さらに好ましくは $100 \text{ W/cm}^2$ 以上である。

【0027】発光時間は、好ましくは $100 \text{ s}$ 以下であり、さらに好ましくは $10 \text{ s}$ 以下である。

【0028】かくしてレーザーにより放出された光エネルギーは、皮膚に塗布された組成物中において、同組成物中に存在する発色団により吸収され、熱エネルギーに変換される。

【0029】好適には、この熱エネルギーで、角質層の組織および表皮の切除のみすることを可能にする。これらの条件下では、上述のように、皮膚への熱エネルギーの伝達によって、真皮において凝集が起ころても、または起ころなくてもよい。処置方法によっては、例えば、活性薬剤の透過力を増大させれば、superficial dermisを凝集させなくて済む。

【0030】本発明に使用する発色団は、好適に、同発色団を含む組成物にレーザーの発光波長において、皮膚中に透過した光エネルギーが好ましくない不可逆的組織損傷あるいは細胞損傷を生じさせないような吸光度を付与するような発色団とする。特に、発色団の使用には、カーボンブラック、グラファイト、鉄黒、ベンガラなどの無機発色団や、メラニン、インドシアニングリーン、染料、その他問題にする波長において十分な吸光度を有する不活性化化学物質(たとえば $1064 \text{ nm}$ においては、ケイ素誘導体、コレステロール誘導体、リン酸塩、硫酸塩など)などの有機発色団の使用などが考えられる。好適には無機発色団を用いる。

【0031】これらの発色団は、油性および／または水性支持体(エマルション、ゲル、軟膏、ポリマーを分散した物、泡状物、エアゾール、懸濁物などが液体媒質中に含まれた形態で、成膜性を有してもよく、エアゾールの形態で存在していてもよい)中に分散させるまたは任意のタイプの生理学的に許容可能なキャリアー中に溶解させることができる。

【0032】これらの発色団および／または同発色団を含有する組成物は、好ましくは発色団が皮膚を透過しないように選択および／または調合する。したがって、発色団は、皮膚を透過しないような適当な粒径を有するか、または組成物がこれらの発色団を凝集体の形態で含有させ、発色団が皮膚を透過しないようにすることができる。

【0033】好ましくない不可逆的組織損傷あるいは細胞損傷は、真皮における毛細血管が損傷され、特に、へ

モグロビンの凝集が起こり、またはメラノサイト、ランゲルハンス細胞、ケラチノサイト、繊維芽細胞、特にこれらの細胞の前駆体が不可逆的に破壊され、さらにこれらの細胞または前駆体中に含まれる水、メラニン、タンパク質などの内因的な発色団の切除により損傷される。

【0034】可視光線および赤外線スペクトル領域で発光するタイプのレーザーは、熱効果を生じさせることを可能にするようなレーザーであればすべて(2)で使用する事ができる。可視光線スペクトル領域で発光するレーザーにはパルス化色素レーザー(585nm)、ルビーレーザー(694nm)および二重Nd:YAGレーザー(532nm)があり、赤外線スペクトル領域で発光するレーザーとしては、CO<sub>2</sub>(10.6μm)、Er:YAG(2.94μm)、Hc:YAG(2.12μm)、Nd:YAG(1.06μm)レーザーなどがある。

【0035】組成物と、同組成物が皮膚表面に塗布された塗布厚の吸光度は、組成物の物理化学的特性と合わせて、レーザーの発光波長に依存する。特に、同吸光度は、発色団のタイプ、同粒径、同発色団製品の分散物の品質、同組成物の濃度および組成などによって変化し、したがって、たとえばカーボンブラックを2.5%で配合した場合、ある種の条件下では0.25%の組成物と同じ吸収スペクトルは示さない。

【0036】したがって、与えられたキャリアー中、与えられた色素濃度において、同一実験条件の下では、色素の分散物の品質が向上すると(トリシリンダー、ultra turaxの使用、色素ペースト通過処理など)、光吸収性が向上する。

【0037】可視光線スペクトル領域または近赤外線スペクトル領域(波長、1μm以下)で発光するレーザーの場合、1つ以上の発色団を含み、レーザー放射線と皮膚の間に配置された組成物により、これらの波長において光を吸収する主たる内因的発色団であるメラニン、ヘモグロビン、オキシヘモグロビンをレーザー照射から保護することができる。したがって、組織の切除が行われると同時に、真皮の内因的化合物を保護する。組織の切除は、本発明の組成物の使用、皮膚表面に同組成物の塗布厚、そして当然のことながら使用するレーザーのパラメータのみに依存する。

【0038】赤外線スペクトル領域(波長、1μm以上)で発光するレーザーの場合、1つ以上の外因的発色団を含み、レーザー放射線と皮膚の間に配置された組成物により、皮膚上に得られる結果が、もはや組織中に含まれる水の分布に依存しないものとする事が可能となる。実際、これらの組織中の水の分布は、問題の部位と、処置を受ける患者の年齢および皮膚のタイプの双方に依存する。したがって、得られた結果は、主として発明にしたがって使用した組成物と皮膚表面に同組成物の塗布厚、そして当然のことながら使用するレーザーのパラメータ

にのみ依存する。

【0039】したがって、与えられた処理(一定の物質の損失と到達深さ)について、特定のレーザーのユーザーの場合、放射照度および光束を、組成物および同組成物を皮膚表面に塗布の厚さの関数として定義することにより、上述の結果が達成される。

【0040】図1〜6は本発明をさらに明らかに示したものであるが、これらの図は、本発明を限定するものではない。これらの図は、ヌードラットの皮膚を図式的に表したものである。

【0041】さらに具体的にいうと、放射照度および光束は、レーザー照射の持続時間が、処理対象の皮膚の熱緩和時間よりも短くなるように選択される。そうすると、熱は皮膚内部に拡散することができ、かつ小さな空間部分に限定されたままの状態となり、組織切除の選択性が高まる。

【0042】組成物、特に膜形成組成物(塗布後乾燥する組成物)は、本発明にしたがって使用される組成物上で用いる波長において光吸収を示さないものであるが、レーザー放射線の照射を行う前に好適に塗布することができる。この添加の目的は、放出されるエネルギーをより小さな相互作用空間部分に限定し、組織切除中に放出される熱弾性波を増幅することにある。したがって、最小の光エネルギーで、隣接組織中に生じる損傷を抑制しながら、組織切除を行うことができる。

【0043】本発明の具体的実施態様によれば、レーザーは、上記皮膚表面を均一かつ再現性よく処置することを可能にするために、レーザーを皮膚に照射するレーザー光線領域に対応する領域よりも広い領域にわたって移動させることのできる装置に接続してもよい。使用する装置は、具体的には米国特許第5,330,517号記載の装置とすることができる。

【0044】

【実施例】ここで、例示により説明するための、ただしなんら発明を制限するものではないが、いくつかの実施例を示す。上記および下記に示す割合は、特に断らない限り、重量%である。

【0045】実施例1：

## ベンガラ(5%)をベースとするO/Wエマルジョン

成分	%
Lanol CTO (Seppic)	
セチルステアリルアルコール	7
Geleol (Gattefosse)	
ステアリン酸グリセリル	2
セチルアルコール	1.5
DC 200、300 cp	
ポリジメチルシロキサン	1.5
Polysynlane (NOF)	
水素化イソパラフィン	15.1
Sicovit red 30E172 (BASF)	
ベンガラ	5
グリセロール	20.1
水	47.8

## 【0046】実施例2:

カーボンブラック(2.5%)をベースとする水性ゲル

成分	%
Derussol A (Degussa)	
カーボンブラック水性分散液	16.65
水	72.85
Aerosil 200 (Degussa)	7.5
プロピレングリコール	2
Poloxamer 182	1

## 【0047】実施例3:

カーボンブラック(2.5%)をベースとする軟膏

成分	%
FW1 (Degussa)	
カーボンブラック	2.5
Polysynlane (NOF)	19.4
適当な親油性分散剤	0.63
石油ジェリー状製剤	77.47

## 【0048】実施例4:

カーボンブラック(2.28%)をベースとする皮膜形成性溶液

成分	%
Derussol A (Degussa)	15.2
Eudragit NE 30 D (Rohm & Haas)	34.7
水	50.1

## 【0049】実施例5:

処置例: 皮膚を滑らかにする処理。

【0050】医薬製剤を添加することによる皮膚を滑らかにする方法は、図1～6により説明することができる。図1は、ヌードラットの表皮および真皮の構造の概略を示したものである。

【0051】医薬製剤の塗布: ヌードラットの皮膚表面(角質層上)に局所的塗布を行う。組成物中に含まれる発色団は角質層上にとどまり、皮膚中には分配されない(図2)。

【0052】レーザー照射: 次の段階は、発光時間が1 $\mu$ sより長い二重化Nd:YAGレーザー(532nm)を用い

て、皮膚表面に照射を行うことからなる(図3)。用いる機構が熱効果なので、放射照度は $10^7$ W/cm<sup>2</sup>以下とする。適用する組成物(実施例1、2に示した組成物)および同組成物の塗布厚は、組織(表皮、真皮)中に透過した光エネルギーが、不可逆的組織損傷あるいは細胞損傷を生じさせるのに十分な量とならないような吸光度を有するものとする。この組成物をレーザー放射線と皮膚の間に配置すれば、血管中のオキシヘモグロビンやヘモグロビンとともに、表皮中のメラニンも照射から保護される。

【0053】組成物を十分な厚さ(実施例1、2で挙げた組成物の場合は約100 $\mu$ m)まで塗布すると、同組成物

中に含まれる発色団により吸収される光エネルギーは、局所的に(同組成物内で)熱エネルギーに変換される(図4)。1回のレーザーショットの間に組成物中に生成された熱は、皮膚内部の熱伝導により伝わり(図5)、温度を局所的に100℃以上まで増大させ、組織切除を達成する(図6)。

【0054】さらに具体的にいうと、実施例2記載の組成物をヌードラットの皮膚表面に厚さおよそ100 $\mu$ mまで塗布した場合、放射照度450W/cm<sup>2</sup>および光束25J/cm<sup>2</sup>で照射することにより、superficial dermisを25~50 $\mu$ mまで凝集させ、同時に表皮から基底層まで切除することができる。8~10日後、このヌードラットの皮膚は、瘢痕形成により再生される。角質層も、皮膚の残りの部分と同様に、瘢痕形成現象により回復する。

【0055】他の外因的発色団を使用して角質層に塗布された組成物の照射条件を変え、前実施例と同様の結果を得ることができる。例を挙げると、実施例1記載の組成物を使用した場合、同じ放射照度(450W/cm<sup>2</sup>)が必要であるが、同一の結果を得るためには2倍近い光束が必要となる。

【図面の簡単な説明】

【図1】 ヌードラットの表皮及び真皮の構造の概略図

である。

【図2】 実施例5に示した方法の第一段階(1)を示す図である。図示したように、発色団を含有する組成物Aを皮膚表面に塗布する。

【図3】 実施例5に示した方法の第二段階(2)を示す図である。レーザーを使って光放射線を照射する。

【図4】 実施例5において、皮膚表面に塗布された組成物と光エネルギーの相互作用空間部分Bを示す図である。同空間部分Bにおいて光エネルギーが熱エネルギーに変換される。

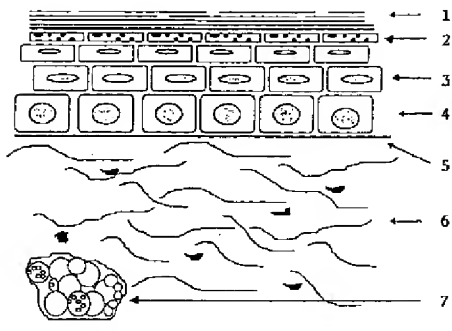
【図5】 実施例5において、熱伝導により加熱される空間部分C(斜線部分)を表す図である。

【図6】 実施例5において、皮膚の組織切除を示す図である。この切除は基底膜まで続く。

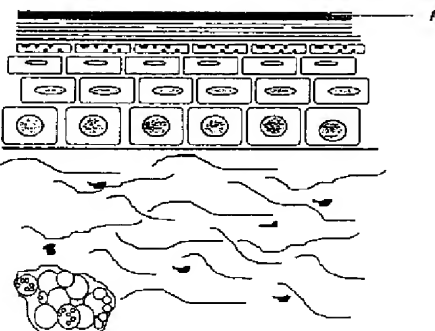
【符号の説明】

- 1：角質層
- 2：顆粒層
- 3：有棘層
- 4：基底層
- 5：基底膜
- 6：真皮
- 7：真皮中の皮脂腺

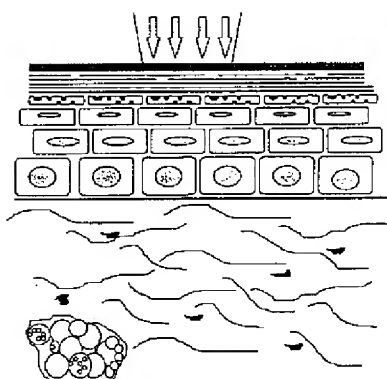
【図1】



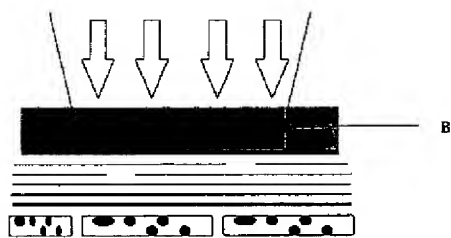
【図2】



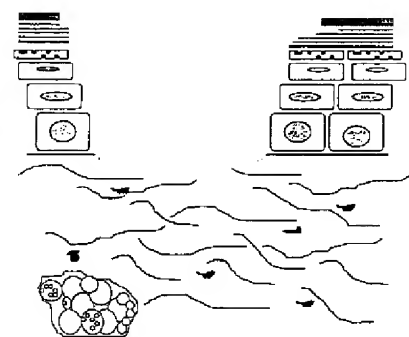
【図3】



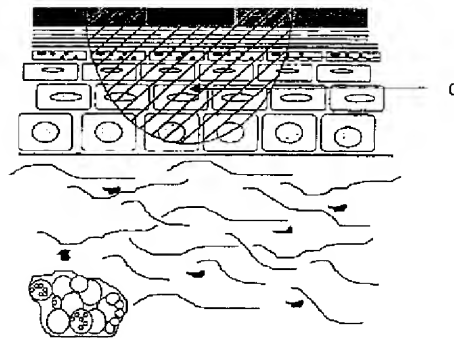
【図4】



【図6】



【図 5】




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フロントページの続き

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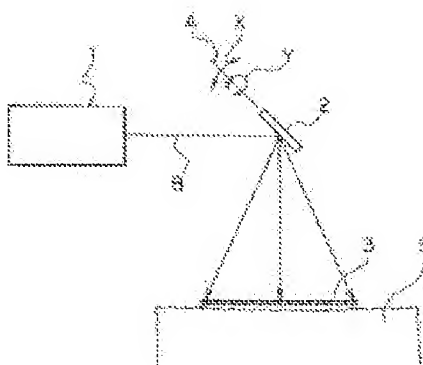
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**LASER APPLICATION DEVICE FOR SKIN TREATMENT****Publication number:** JP11047146 (A)**Publication date:** 1999-02-23**Inventor(s):** UTSUKI RYUICHI**Applicant(s):** UTSUKI RYUICHI**Classification:****- international:** **A61B18/20; A61N5/06; A61B18/20; A61N5/06; (IPC1-7): A61B17/36; A61N5/06****- European:****Application number:** JP19970206435 19970731**Priority number(s):** JP19970206435 19970731**Also published as:** JP4014255 (B2)**Abstract of JP 11047146 (A)**

**PROBLEM TO BE SOLVED:** To easily perform treatments such that parts requiring different cauterization levels are juxtaposed. **SOLUTION:** A laser application device has a beam scan means 2 applying a laser beam to the area for cauterization by scanning, and has a cauterization control means 3 for juxtaposing a first cauterization level part where cauterization depth in the skin is great and a second cauterization level part where the cauterization level is shallower than in the first cauterization level part, or an uncauterized part, during the application of the laser beam in the scanning fashion.



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(19) 日本国特許庁 (J P)

(12) 公開特許公報 (A)

(11) 特許出願公開番号

特開平11-47146

(43) 公開日 平成11年(1999) 2月23日

(51) Int.Cl.<sup>6</sup>

A 6 1 B 17/36

A 6 1 N 5/06

識別記号

3 5 0

F I

A 6 1 B 17/36

A 6 1 N 5/06

3 5 0

E

審査請求 未請求 請求項の数 4 O L (全 4 頁)

(21) 出願番号

特願平9-206435

(22) 出願日

平成9年(1997) 7月31日

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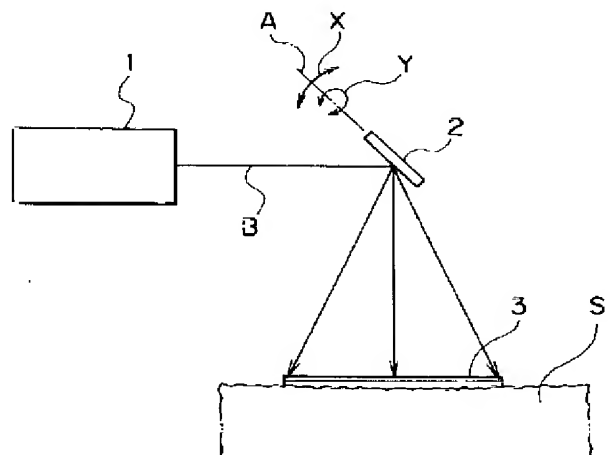
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(54) 【発明の名称】 皮膚治療用のレーザー照射装置

(57) 【要約】

【課題】 焼灼レベルの異なる部分を混在させる治療を簡単に行なうことのできる皮膚治療用のレーザー照射装置の提供。

【解決手段】 レーザ照射装置は、焼灼対象領域に対し走査的にレーザービームを照射するビーム走査手段2を備えるとともに、走査的なレーザービームの照射に際して、皮膚に対する焼灼深さが深い第1の焼灼レベル部分と、この第1の焼灼レベル部分より浅い焼灼レベルの第2の焼灼レベル部分または非焼灼部分とを混在させるための焼灼制御手段3を備えている。



**【特許請求の範囲】**

【請求項1】 皮膚の所定領域に焼灼を施す治療に用いるレーザ照射装置において、焼灼対象領域に対し走査的にレーザビームを照射するためのビーム走査手段を備えるとともに、走査的なレーザビームの照射に際して、皮膚に対する焼灼深さが深い第1の焼灼レベル部分と、この第1の焼灼レベル部分より浅い焼灼レベルの第2の焼灼レベル部分または非焼灼部分とを混在させるための焼灼制御手段を備えたことを特徴とするレーザ照射装置。

【請求項2】 焼灼制御手段は、レーザ光に対する透明性の高い第1の透明レベル部と、この第1の透明レベル部より透明性の低い第2の透明レベル部を所定のパターンで有するマスクである請求項1に記載のレーザ照射装置。

【請求項3】 焼灼制御手段は、レーザビームをパルス化し、且つ各パルスのパワーを所定のパターンで異ならせる制御をなすようになっている請求項1に記載のレーザ照射装置。

【請求項4】 焼灼制御手段は、レーザビームに中抜けたなプロファイルを与えると同時に、この中抜け状態のレーザビームを断続的に照射する制御をなすようになっている請求項1に記載のレーザ照射装置。

**【発明の詳細な説明】****【0001】**

【発明の属する技術分野】本発明は、例えばしわ取り治療などのように、皮膚の所定領域に焼灼を施す治療に用いるレーザ照射装置に関する。

**【0002】**

【発明の背景】レーザビームの照射により皮膚を治療することが広く行なわれている。その一つとしてしわ（皺）取り治療がある。しわ取り治療は、レーザビームの照射で皮膚の特定領域を一定の深さで焼灼することにより行なわれる。しわ取り治療の効果は、基本的には、皮膚をレーザビームで焼灼する深さに左右され、焼灼深度が深いほど効果的な治療ができる。しかし深い焼灼は、皮膚の再生治療を遅延させ、瘢痕形成や色素沈着、色素脱失の原因となる。このため、焼灼の深さには限界があり、十分な治療効果が得られないという問題があった。

【0003】またこのようなしわ取り治療は、白色人種系の人についてその例が多く、有色人種系の人については比較的少ない。その理由は、有色人種の皮膚が元来、白色人種よりもレーザ照射後の色素沈着、色素脱失、瘢痕などを来たしやすく、皮膚そのものが厚いということにも関係していると考えられる。すなわち白色人種系の人、比較的皮膚が薄いため、浅く焼灼するだけでも有効なしわ取り効果を得ることができる。一方、有色人種系の人、比較的皮膚が厚く、有効なしわ取りとするにはかなり深く焼灼する必要がある。そのため深い焼灼に伴う色素沈着や瘢痕などが残る可能性が大きく、このこ

とが有色人種系の人にしわ取り治療を施す上で大きな障害となっている。

【0004】このような事情から本願発明者は、出来るだけ深く焼灼できて、なお且つ色素沈着や瘢痕などを残す可能性の小さい治療法について研究を重ねて来た。その結果、有効なしわ取り効果を得るには、真皮に達するレベルの焼灼を基本的に必要とするものの、このレベルの焼灼は焼灼しようとする領域全体に必ずしも均一にある必要のないことを見出した。つまり本願発明者の新たな知見によると、浅いレベルの焼灼部分や非焼灼部分が深いレベルの焼灼部分に混じって散在するようにしても、十分に有効なしわ取り効果を得ることが可能であり、しかもこのように浅いレベルの焼灼部分や非焼灼部分を深いレベルの焼灼部分に混在させることで、表皮の基底層による再生能力を残存させることができ、瘢痕や色素沈着、色素脱失の発生を効果的に防止することもできる。

**【0005】**

【発明が解決しようとする課題】上記のような焼灼レベルの異なる部分を混在させる治療法は、これを簡単に行なうことのできるレーザ照射装置を実現することで初めて効果的に施すことができる。したがって本発明の目的は、そのような皮膚治療用のレーザ照射装置の提供にある。

**【0006】**

【課題を解決するための手段】本発明によるレーザ照射装置は、皮膚の所定領域に焼灼を施す治療に用いるものであり、焼灼対象領域に対し走査的にレーザビームを照射するためのビーム走査手段を備えるとともに、走査的なレーザビームの照射に際して、皮膚に対する焼灼深さが深い第1の焼灼レベル部分と、この第1の焼灼レベル部分より浅い焼灼レベルの第2の焼灼レベル部分または非焼灼部分とを混在させるための焼灼制御手段を備えている。

【0007】このレーザ照射装置によると、例えばコンピュータなどにより設定した領域に対しビーム走査手段により自動的にレーザビームを走査させることで、目的の焼灼領域に対しレーザビームを照射することができる。しかもこの走査的な照射に際して、焼灼制御手段により、第1の焼灼レベル部分（深いレベルの焼灼部分）の間に第2の焼灼レベル部分（浅いレベル焼灼部分）や非焼灼部分を自動的に混ぜ込ませることができる。このため上記のような治療法による治療を容易に施すことが可能となる。

【0008】このようなレーザ照射装置によりしわ取り治療を行なう場合には、第1の焼灼レベルは、少なくとも真皮に達するレベルとし、第2の焼灼レベルは表皮の基底層に達することのない深さ以下とするのが好ましい。

【0009】上記のようなレーザ照射装置における焼灼

制御手段には種々の方式が可能である。好ましい方式としては、マスク方式やパルス方式あるいはビームプロファイル方式などがある。マスク方式は、レーザ光に対する透明性の高い第1の透明レベル部と、この第1の透明レベル部より透明性の低い第2の透明レベル部を所定のパターンで有するマスクを用いることで、第1の焼灼レベル部分と第2の焼灼レベル部分または非焼灼部分との混在を与える方式である。この場合、第1の透明レベル部はレーザ光に対し完全に透明にするのが通常である。一方、第2の透明レベル部は、完全に不透明とするか、または適度な透過性を与えるようにする。第2の透明レベル部を完全不透明とする場合には、第1の焼灼レベル部分と非焼灼部分とが混在することになり、第2の透明レベル部に適度な透過性を与える場合には、第1の焼灼レベル部分と第2の焼灼レベル部分とが混在することになる。

【0010】パルス方式は、レーザビームをパルス化し、且つ各パルスのパワーを所定のパターンで異ならせる制御、つまりパワーの異なるレーザビームを所定の繰り返しパターンで断続的に照射する制御をなすことで、第1の焼灼レベル部分と第2の焼灼レベル部分または非焼灼部分との混在を与える方式である。この方式では、第1の焼灼レベル部分を与えるパワーのパルスのみを一定間隔で照射することにより、第1の焼灼レベル部分と非焼灼部分を混在させることができる。また第1の焼灼レベル部分を与えるパワーのパルスと、これよりもパワーの小さいパルスとを組み合わせる照射することにより、第1の焼灼レベル部分と第2の焼灼レベル部分とを混在させることができる。

【0011】ビームプロファイル方式は、レーザビームに例えばドーナツ状のように中心部分が抜ける中抜け的なプロファイルを与え、この中抜け状態のレーザビームを断続的に照射する制御をなすことで、第1の焼灼レベル部分と第2の焼灼レベル部分または非焼灼部分との混在を与える方式である。そのプロファイルにおける中抜け状態は、中心部分のパワーを周辺部のパワーよりも小さくすることで与える。つまり中心部分のパワー $P_c$ が周辺部のパワー $P_s$ に対し $0 \leq P_c < P_s$ となるようにする。

#### 【0012】

【実施の形態】以下本発明の実施形態について説明する。第1の実施形態によるレーザ照射装置は、マスク方式の焼灼制御手段を備えたタイプである。その構成を図1に模式化して示す。図1に見られるようにレーザ照射装置は、レーザ発振ユニット1、ビーム走査手段であるミラー2、及びマスク3を備える。レーザ発振ユニット1から射出したレーザビームBは、ミラー2で反射した後、マスク3を介して皮膚Sを照射する。ミラー2は、図示せぬコンピュータなどによる制御の下でミラー2の中心軸Aに対する矢印Xや矢印Yの如き回動を行ない、

これに応じてレーザビームBを目的の焼灼領域にジグザグ的走査で照射する。

【0013】マスク3は、図2にその一例を示すように、レーザ光に対し完全に透明である第1の透明レベル部3aと完全に不透明であるか、または適度な透過性を与えた第2の透明レベル部3bを交互的に配したパターンに形成することができる。このようなマスク3は、レーザ光に対し完全に透明である基材に不透明化処理を施したり、あるいはレーザ光に対し完全に不透明である基材を切り抜くなどして形成することができる。

【0014】第2の実施形態によるレーザ照射装置は、パルス方式の焼灼制御手段を備えたタイプであり、図3に示すように、レーザ発振ユニット1にパルス制御手段5を接続してある。パルス制御手段5は、レーザ発振ユニット1を制御してレーザビームBをパルス化するとともに、各パルスのパワーを所定のパターンで異ならせる。そのパルスパターンの例を図4に示す。図4の

(a)は、第1の焼灼レベルを与えるパワーのパルスのみを一定間隔で照射するパターンであり、図4の(b)は、第1の焼灼レベルを与えるパワーのパルスと、これよりもパワーの小さいパルスとを組み合わせるパターンである。

【0015】第3の実施形態によるレーザ照射装置は、ビームプロファイル方式の焼灼制御手段を備えたタイプであり、図5に示すように、レーザ発振ユニット1とミラー2の間にプロファイル形成手段6を備えており、このプロファイル形成手段6によりレーザビームBに所定のプロファイルを与える。そのプロファイルは、図6に一例を示すように、中抜け状態とする(図中にハッチングを施した部分がパワー零の部分である)。また発振制御手段7を備えており、レーザビームBを断続的に照射する制御を行なう。このようなレーザ照射装置による焼灼のパターンは図7に示すようになる。図中の○が非焼灼部分である。

【0016】以上の実施形態ではビーム走査手段にミラーを用いてジグザグ的走査をなさせるようにしていたが、この他にも例えばレンズなどを用いてラセン的走査などを行なわせることも可能である。

#### 【0017】

【発明の効果】以上説明したように、本発明によると、非焼灼または浅い焼灼レベルの部分に混在させることで、従来の均一に焼灼する方法よりも、速やかに皮膚の再生治癒が得られる。このため治癒時間が遅延することなく、より深い焼灼が可能となり、より治療効果の高いしわ取り治療を行なうことができる。また速やかな治癒は、色素沈着、色素脱失、瘢痕形成などを来す可能性がより少なくなり、例えば皮膚の厚い人や色素沈着を来しやすい有色人種系の人にもしわ取り治療を施しやすくなる。

#### 【図面の簡単な説明】

【図1】第1の実施形態によるレーザ照射装置の構成図。

【図2】マスクの平面図。

【図3】第2の実施形態によるレーザ照射装置の構成図。

【図4】パルスパターンの説明図。

【図5】第3の実施形態によるレーザ照射装置の構成図。

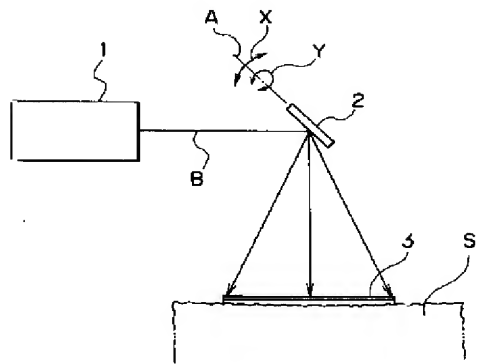
【図6】レーザビームのプロファイルの説明図。

【図7】第3の実施形態によるレーザ照射装置による焼灼のパターンの説明図。

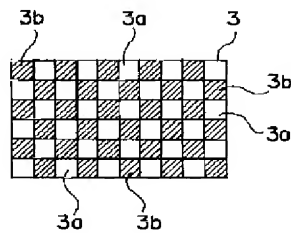
【符号の説明】

- 1 レーザ発振ユニット
- 2 ミラー（ビーム走査手段）
- 3 マスク
- 5 パルス制御手段
- 6 プロファイル形成手段
- 7 発振制御手段

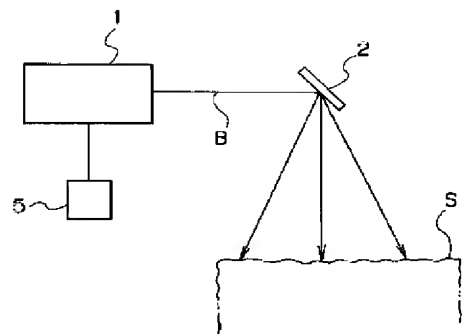
【図1】



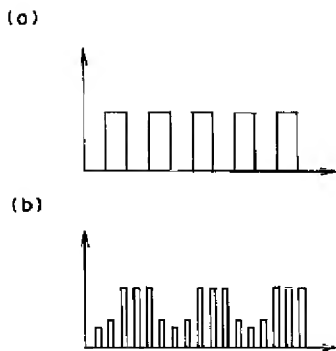
【図2】



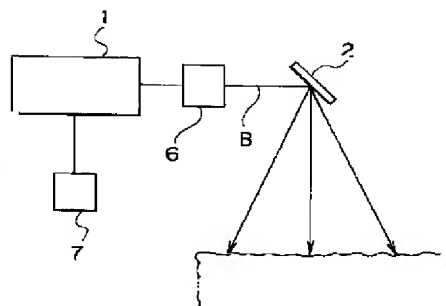
【図3】



【図4】



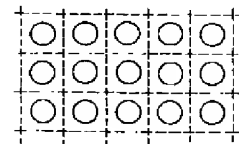
【図5】



【図6】



【図7】



**FRONT SURFACE COOLING METHOD AT THE TIME OF LASER IRRADIATION**

**Publication number:** JP2000037400 (A)

**Publication date:** 2000-02-08

**Inventor(s):** KANEDA MICHIIRO

**Applicant(s):** NIPPON SEKIGAISEN KOGYO KK

**Classification:**

- **international:** **A61B18/20; A61N5/06; H01S3/041; A61B18/20; A61N5/06; H01S3/04; (IPC1-7): A61B18/20; A61N5/06; H01S3/041**

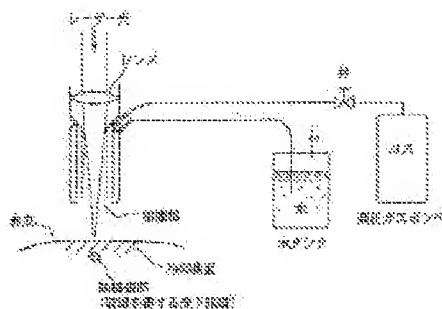
- **European:**

**Application number:** JP19980225383 19980723

**Priority number(s):** JP19980225383 19980723

Abstract of **JP 2000037400 (A)**

**PROBLEM TO BE SOLVED:** To obtain an efficient and easy front surface cooling method at the time of a laser irradiation. **SOLUTION:** In a method for destroying a specified subcutaneous tissue and medically treating it by the irradiation of a laser beam, a mist-state liquid is sprayed to an epidermis above the subcutaneous tissue and also gas is blown so that the vaporization of the liquid is promoted and the heat of the epidermis is taken away by the heat of vaporization. Then, the epidermis is cooled.



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(19) 日本国特許庁 (J P)

(12) 公開特許公報 (A)

(11) 特許出願公開番号  
特開2000-37400  
(P2000-37400A)

(43) 公開日 平成12年2月8日(2000.2.8)

(51) Int.Cl. <sup>7</sup>	識別記号	F I	テーマコード* (参考)
A 6 1 B 18/20		A 6 1 B 17/36	3 5 0 4 C 0 2 6
A 6 1 N 5/06		A 6 1 N 5/06	E 4 C 0 8 2
H 0 1 S 3/041		H 0 1 S 3/04	C 5 F 0 7 2

審査請求 未請求 請求項の数 4 F D (全 3 頁)

(21) 出願番号 特願平10-225383

(22) 出願日 平成10年7月23日(1998.7.23)

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Fターム(参考) 4C026 AA04 DD06

4C082 RA02 RG06

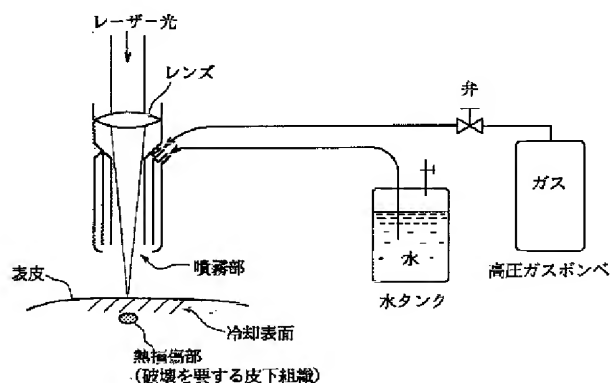
5F072 HH09 YY01

(54) 【発明の名称】 レーザー照射時の表面冷却方法

(57) 【要約】

【課題】効率的で且つ簡便なレーザー照射時の表面冷却方法を得る。

【解決手段】レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、該皮下組織上の表皮に霧状の液体を噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、気化熱によって表皮の熱を奪い去ることにより表皮を冷却することを特徴とするレーザー照射時の表面冷却方法。



【特許請求の範囲】

【請求項1】レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、該皮下組織上の表皮に霧状の液体を噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、気化熱によって表皮の熱を奪い去ることにより表皮を冷却することを特徴とするレーザー照射時の表面冷却方法。

【請求項2】上記液体が水又は水とアルコールの混合液であり、上記ガスが圧縮された空気又は窒素ガスである請求項1記載のレーザー照射時の表面冷却方法。

【請求項3】上記霧状液体の噴霧とガスの吹き付けを、レーザー射出部に液体噴霧装置とガスジェットを設置することにより行うことを特徴とする請求項1記載のレーザー照射時の表面冷却方法。

【請求項4】上記液体噴霧装置とガスジェットをレーザーの照射と同期するようにし、レーザー照射の直前に表皮の冷却を行うことを特徴とする請求項1記載のレーザー照射時の表面冷却方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、レーザー照射時の表面冷却方法に関し、より具体的にはレーザー光の照射によって特定の皮下組織を破壊して治療を行うに際して表皮の冷却を効率的且つ簡便に行うようにしてなるレーザー照射時の表面冷却方法に関する。

【0002】

【従来の技術】レーザー光は医療分野において外科用メスや癌への応用などに適用されてきている。レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、表皮の損傷を低減するため、表皮を冷却しながらレーザー照射を行う方法が開発されている。現在開発されている冷却方法には冷温ガスを直接吹き付ける方法と冷水により冷却された固体を皮膚に接触させて冷却する方法がある。冷却された固体は、レーザー光が透過できるようにガラス・石英等の光学材料で構成されている。

【0003】ところが、冷温ガスを直接吹き付ける方法では、冷温ガスを生成させるための冷却装置が必要であるのに加え、冷温ガスの熱容量が小さいため、十分な冷却効果を得るためには多量の冷温ガスを吹き付ける必要がある。また、冷水により冷却された固体を皮膚に接触させて冷却する方法では、別途冷水により固体を冷却するための機構が必要であるばかりか、レーザー光をガラスや石英等の光学材料に透過させる必要があるため、レーザー光にロスが生じる等の問題がある。

【0004】

【発明が解決しようとする課題】本発明は、レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法における、上記のような欠点を解決するためになされたものであり、表皮表面に液体を噴霧してその気化熱によ

り表皮の熱を奪い去ることにより、効率的で且つ簡便なレーザー照射時の表面冷却方法を提供することを目的とする。

【0005】

【課題を解決するための手段】すなわち本発明は、レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、該皮下組織上の表皮に霧状の液体を噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、気化熱によって表皮の熱を奪い去ることにより表皮を冷却することを特徴とするレーザー照射時の表面冷却方法を提供する。

【0006】

【発明の実施の形態】本発明においては、レーザー光を照射する必要のある表皮面に液体を霧状に噴霧するとともに、ガスを吹き付けることにより、該液体の気化を促進し、その気化熱によって表皮の熱を奪い去ることにより冷却する。使用液体としては、ガスを吹き付けることにより気化する液体であれば特に限定はないが、好ましくは水又は水とアルコールとの混合液が用いられる。また、吹き付け用のガスとしては空気や窒素ガス等適宜のガスが使用される。

【0007】液体の噴霧装置とガスの吹き付け装置（ガスジェット、ガスジェットノズル）はレーザー出射部に一体化して配置するのが好ましい。レーザー光は凸レンズを通して集光され生体中破壊が必要な皮下組織すなわち熱損傷部に照射されるが、液体噴霧装置とガスジェットはレーザー出射部を囲って配置するのが望ましい。

【0008】この場合、ガスは圧縮状態（加圧状態）で供給される必要があるが、圧縮ガスは例えば高压ガスボンベからのガスをを用いることで供給することができる。また液体はタンクから導管を通して噴霧装置に供給するが、圧縮ガスによるガスジェットの吸引作用により供給することができる。すなわちその操作時に1種のエジェクター作用を利用する。その際、液体供給用のポンプを併用して供給してもよいことは勿論である。

【0009】図1は本発明で使用し得る装置態様例の概略図である。図示のとおり、レーザー光は凸レンズで集光され、生体中の患部等、すなわち損傷することが必要な皮下組織部分（熱損傷部）に照射される。レンズを経た後表皮に至るまでがレーザー出射部に相当するが、該出射部を順次円筒状に囲んで、ガス供給円管及び液体供給円管が形成されている。液体供給円管を内側に、ガス供給円管を外側に配置してもよい。

【0010】高压ガスボンベ中のガスは導管、弁を介して出射部を囲むガス用円管に供給され、その下端部から噴射される。その際、液体タンク中の液体、例えば水は圧縮噴射ガスの吸引作用により液体導管を経て吸引されて、ガス用円管を囲む液体用円管に導入され、噴射部から噴霧される。ガス供給部及び液体供給部の先端によって噴霧部すなわちノズルが形成され、レーザー照射時、



またはその直前に霧状の液体を表皮に噴霧するとともに、ガスを吹き付ける。これにより、液体の気化を促進し、気化熱として表皮の熱を奪い去ることができる。

【0011】表皮は予め冷却しておくのが望ましい。このため霧状の液体の噴霧とガスを吹き付け時期は、レーザー照射直前であるのがよいが、このため液体噴霧装置とガスジェット(ガスジェットノズル)をレーザーの照射と連動・同期するようにし、レーザー照射の直前に液体噴霧装置からの液体噴霧とガスジェットからのガス吹き付けをレーザー照射の直前に行うようにするのが望まし

い。

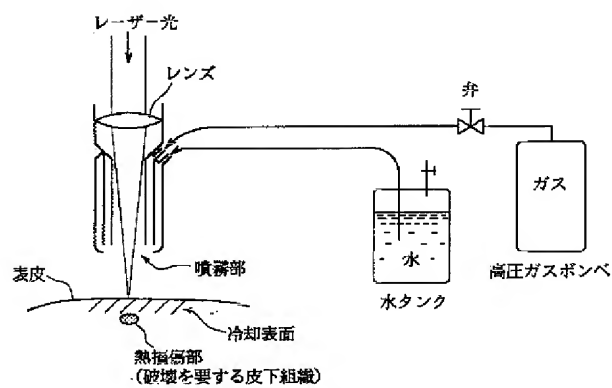
【0012】

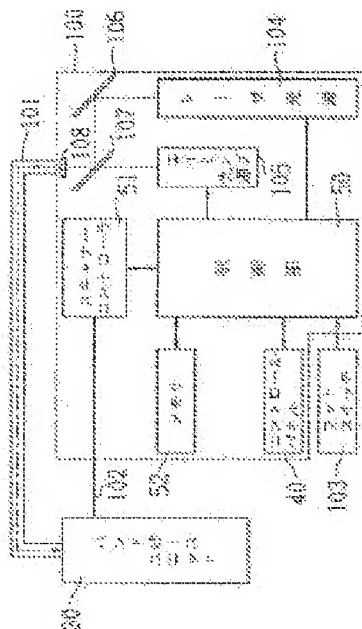
【発明の効果】本発明によれば、レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、霧状の液体を表皮に噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、その気化熱によって表皮の熱を奪い去ることにより表皮を効果的且つ簡便に冷却することができる。

【図面の簡単な説明】

【図1】本発明で使用し得る装置態様例の概略図。

【図1】







【特許請求の範囲】

【請求項1】 治療レーザー光源からのレーザー光をスポット状に形成して患部に導光照射するための導光光学系と、該導光光学系に配置され患部領域にスポット照射される前記レーザー光のスポット位置を走査するための走査手段と、前記走査手段によるスポット位置の走査が連続して隣り合わないよう各スポット位置の照射順序を定める順序決定手段と、該順序決定手段により定められた各スポット位置の照射順序に従ってレーザー照射が行われるように前記走査手段を制御する制御手段と、を備えることを特徴とするレーザー治療装置。

【請求項2】 請求項1のスポット位置とは、前記走査手段によるレーザー光の照射位置の走査を停止させることによりレーザー光がスポット照射される位置であることを特徴とするレーザー治療装置。

【請求項3】 請求項1のレーザー治療装置において、レーザー光の照射領域を可変設定する領域設定手段を備え、前記順序決定手段は設定された照射領域に応じて定められるレーザー光のスポット位置の分布に基づいて各スポット位置の走査が連続して隣り合わないような規則的な照射順序を定めることを特徴とするレーザー治療装置。

【請求項4】 請求項3のレーザー治療装置において、前記領域設定手段により1つのライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1ライン上でのスポット位置を少なくとも1つ飛びに順次走査させるよう照射順序を定めることを特徴とするレーザー治療装置。

【請求項5】 請求項4のレーザー治療装置において、前記順序決定手段は1ライン上のスポット位置の数に応じて初期照射のスポット位置を定めることを特徴とするレーザー治療装置。

【請求項6】 請求項3のレーザー治療装置において、前記領域設定手段により複数のライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1つのライン上でのスポット位置を所定数の間隔おきに順次走査させた後に次のライン上へスポット位置を移すように照射順序を定めることを特徴とするレーザー治療装置。

【請求項7】 請求項1のレーザー治療装置において、レーザー光の照射領域の形状パターンとそのサイズを設定する領域設定手段と、レーザー照射の形状パターンとそのサイズに応じて各スポット位置の走査が連続して隣り合わないような規則的な照射順序が定められた照射順序パターンを複数個記憶する記憶手段と、を備え、前記順序決定手段は前記領域設定手段による形状パターンとそのサイズの設定に基づいて前記記憶手段の中から照射順序パターンを決定することを特徴とするレーザー治療装置。

【請求項8】 請求項1の走査手段は、レーザー光を反射する2枚のミラーと、各ミラーを揺動させるための揺動手段とを備え、該揺動手段による2枚のミラーを個別に

揺動することにより患部領域上でレーザー光のスポット位置を2次元的に走査するレーザー走査手段であることを特徴とするレーザー治療装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、治療部位に治療レーザー光を照射して治療を行うレーザー治療装置に関する。

【0002】

【従来技術】従来より、皮膚にレーザー光を照射して、脱毛、皴取り、痣取り等を行うレーザー治療装置が知られている。例えば、レーザー脱毛治療は毛根周辺にレーザー光を照射することにより、その熱エネルギーが毛根部に放熱されて毛根が焼灼されることにより脱毛が行われるものであるが、レーザー光の照射を1パルスずつ行なうような脱毛の治療方法は時間が掛かってしまい効率が悪い。そのため、一度に照射する領域を予め設定しておき、2枚の駆動ミラー等を使用することによってその照射領域にレーザー光のビームスポット（スポット位置）を並べるように走査（スキヤニング）していき、設定した照射範囲全体をもれなく照射して効率よく脱毛が行われるようにしている。

【0003】

【発明が解決しようとする課題】しかしながら、従来のビームスポットの走査は、図5に示すように、照射領域の1ライン目の端から順番に隣へ走査し、これを順次2ライン目、3ライン目と繰り返していくように定められていた。このようなビームスポットの走査の順番であると、最初に照射された時のビームスポットにおける熱緩和時間（レーザー光をターゲットに照射した時、ターゲット周囲の温度分布はその直径で決まる幅を持つガウシアン分布となるが、その分布の中心温度が50%に下がるまでの時間）の影響が考慮されずに隣りのスポット位置に次のビームが照射されてしまうため、皮膚への熱ダメージ（サーマルダメージ）が起こり易いという問題があった。

【0004】本発明は、上記従来装置の欠点に鑑み、レーザー光の連続照射による皮膚への熱ダメージを軽減することができる装置を提供することを技術課題とする。

【0005】

【課題を解決するための手段】上記課題を解決するために、本発明は以下のような構成を備えることを特徴とする。

【0006】（1） 治療レーザー光源からのレーザー光をスポット状に形成して患部に導光照射するための導光光学系と、該導光光学系に配置され患部領域にスポット照射される前記レーザー光のスポット位置を走査するための走査手段と、前記走査手段によるスポット位置の走査が連続して隣り合わないよう各スポット位置の照射順序を定める順序決定手段と、該順序決定手段により定められた各スポット位置の照射順序に従ってレーザー照射が行

われるように前記走査手段を制御する制御手段と、を備えることを特徴とする。

【0007】(2) (1)のスポット位置とは、前記走査手段によるレーザ光の照射位置の走査を停止させることによりレーザ光がスポット照射される位置であることを特徴とする。

【0008】(3) (1)のレーザ治療装置において、レーザ光の照射領域を可変設定する領域設定手段を備え、前記順序決定手段は設定された照射領域に応じて定められるレーザ光のスポット位置の分布に基づいて各スポット位置の走査が連続して隣り合わないような規則的な照射順序を定めることを特徴とする。

【0009】(4) (3)のレーザ治療装置において、前記領域設定手段により1つのライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1ライン上でのスポット位置を少なくとも1つ飛びに順次走査させるよう照射順序を定めることを特徴とする。

【0010】(5) (4)のレーザ治療装置において、前記順序決定手段は1ライン上のスポット位置の数に応じて初期照射のスポット位置を定めることを特徴とする。

【0011】(6) (3)のレーザ治療装置において、前記領域設定手段により複数のライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1つのライン上でのスポット位置を所定数の間隔おきに順次走査させた後に次のライン上へスポット位置を移すように照射順序を定めることを特徴とする。

【0012】(7) (1)のレーザ治療装置において、レーザ光の照射領域の形状パターンとそのサイズを設定する領域設定手段と、レーザ照射の形状パターンとそのサイズに応じて各スポット位置の走査が連続して隣り合わないような規則的な照射順序が定められた照射順序パターンを複数個記憶する記憶手段と、を備え、前記順序決定手段は前記領域設定手段による形状パターンとそのサイズの設定に基づいて前記記憶手段の中から照射順序パターンを決定することを特徴とする。

【0013】(8) (1)の走査手段は、レーザ光を反射する2枚のミラーと、各ミラーを揺動させるための揺動手段とを備え、該揺動手段による2枚のミラーを個別に揺動することにより患部領域上でレーザ光のスポット位置を2次元的に走査するレーザ走査手段であることを特徴とする。

【0014】

【発明の実施の形態】本発明の形態を図面に基いて説明する。図1は実施の形態である脱毛用のレーザ治療装置の外観略図を示す。

【0015】100はレーザ装置本体であり、装置本体100内部には後述する制御部50、脱毛用レーザ光源104、エイミング光源105等が収納されている(図

4参照)。レーザ光源104は本形態では連続波(CW)を射出する半導体レーザ(波長835nm)を使用している。また、エイミング光源105は半導体レーザ(波長600nm)を使用している。

【0016】40は照射サイズ、照射密度等のレーザ照射条件等の各種設定条件を入力するためのコントロールパネルである(詳しくは後述する)。101は装置本体1から射出されるレーザ光を導光するための光ファイバー、30はレーザ照射口を持つハンドピースユニットである。102はハンドピースユニット103内部に設置してあるレーザ走査用のミラー32a、32b(図2参照)を駆動させるための電気信号を送るケーブル、103はレーザ光を照射するためのトリガ信号を発信するためのフットスイッチである。

【0017】図2はハンドピースユニット30の概略構成を示す図である。ハンドピースユニット30内には、光ファイバ101内を通過してきたレーザ光を集光するレンズ31a、レンズ31bと、レーザ光を治療部位でXY方向にスキャンさせるための駆動ミラー32a、32bと、各ミラー32a、32bを揺動する駆動モータ33a、33bを備える。レーザ装置本体100からのレーザ光は光ファイバ101を介してハンドピースユニット30に導かれ、光ファイバ101を射出したレーザ光はレンズ31a、レンズ31により照射部位上で直径4mm程度のスポット状に形成されて患部に導光される。

【0018】駆動モータ33a、33bは装置本体100内に設けられたスキャナーコントローラ51により制御される(図4参照)。スキャナコントローラ51は制御信号をケーブル102を介してハンドピースユニット30に送信し、駆動モータ33a及び駆動モータ33bの回転をそれぞれ駆動制御することにより、駆動ミラー32a及び駆動ミラー32bを揺動し、レーザビームの照射のスポット位置を走査させる(走査させる)。なお、34は皮膚に当接させハンドピースユニット30を安定させるとともにレーザ光の集光距離を一定にさせるための位置決めガイドである。

【0019】図3はコントロールパネル40の構成を示した図である。41はモード選択スイッチであり、スキャンニングによるレーザ照射(SCAN)、またはスキャンニングさせずに1点照射(BEAM)のモードを選択することができる。42はレーザ照射のスキャンニング形状を選択するための照射形状スイッチであり、スイッチの切替により正方形、長方形、直線、六角形の4種類から選ぶことができる。43は照射形状スイッチ42で選択した照射形状の大きさを変更するための照射サイズスイッチである。照射形状のサイズはそれぞれの照射形状に対して数種類のサイズパターンが予め記憶されている。

【0020】44は照射するビームスポット同士の重なり具合(以下、照射密度と記す)を設定するための照射

密度スイッチである。照射密度スイッチ44により照射密度を、隣どうしのビームスポットが全く重ならず隣接させる照射密度となる0%をはじめ、5、10、15、20、25、30%の7種類から選択できる。45は1照射時間を10～100msecの間に5msecステップで変更設定するための照射時間設定スイッチである。46は1回のスキヤニングにてレーザ光をOFFするかどうかの設定を行なうシングル設定スイッチである。47は設定されたレーザ照射条件を表示するモニタである。

【0021】次に、以上のような構成を備えるレーザ治療装置において、その動作について図4の制御系及び光学系（レーザ装置本体100側のみ示している）の要部図に基づき説明する。

【0022】電源を投入するとレーザ治療装置はセルフチェックを開始する。スキヤニングによるレーザ照射を行う場合は、セルフチェックの完了後に術者はモード選択スイッチ41を使用してスキヤニングのモードにする。次に、ハンドピースユニット30からの治療用レーザ光が患者の治療部位（脱毛部位）に当たるように位置決めガイド34を治療部付近に当接させる。

【0023】ハンドピースユニット30からはエイミング光源105によるエイミング光が照射されるので、術者はエイミング光の照射位置を確認しながら照射形状スイッチ42、照射サイズスイッチ43、照射密度スイッチ44等を使用し、レーザ光照射条件を設定する。

【0024】設定されたレーザ光照射条件の信号は制御部50を介してスキヤナーコントローラ51に送られる。スキヤナーコントローラ51は設定されたレーザ光照射条件にしたがって制御信号を送信し、駆動モータ33a、33bを駆動させ、駆動ミラー32a、32bを揺動させる。このときエイミング光は前述した駆動ミラー32a、32bの揺動により、設定された照射形状及び照射サイズに基づいて、その輪郭形状を走査するように照射される。

【0025】術者はレーザ光照射条件の設定とエイミング光の観察による照射部位の特定ができたらずットスイッチ103を踏み込むことによりトリガ信号を発信させる。制御部50は、レーザ光源104から治療用レーザ光を出射させる。レーザ光源104を出射した治療用レーザ光は、ミラー106、ダイクロイックミラー107によって反射された後、エイミング光と同軸にされる。エイミング光と同軸にされた後、集光レンズ108によって光ファイバ101に集光、入射される。光ファイバ101に入射された治療用レーザ光（及びエイミング光）はハンドピースユニット30に導光される。

【0026】また、フットスイッチ103からのトリガ信号は制御部40を介してスキヤナーコントローラ51に入力されており、スキヤナーコントローラ51は設定されたレーザ光照射条件にしたがって制御信号を送信し、駆動モータ33a、33bを駆動させ、駆動ミラー

32a、32bを揺動させる。この駆動ミラー32a、32bの揺動により、ハンドピースユニット30に導光された治療レーザ用レーザ光は設定した照射形状及び照射サイズに基づいてスキヤニングされ、患部に照射される。

【0027】次に、本形態のスキヤニング制御によるレーザ照射のスポット位置の順序について、図6～図9を用いて各スキヤニング形状毎（照射領域の形状毎）にそれぞれ説明する。

【0028】まず、本形態によるスキヤニング制御の説明に先立ち、従来のレーザ治療装置における治療用（脱毛用）レーザ光のスキヤニング方法を図5により説明する。図5はスキヤニング形状が正方形で4（ビームスポット）×4（ライン）の場合のスキヤニング方法を示した図である。図において、丸印はレーザ光が照射されるビームスポット位置を、丸印内の数字はスキヤニングの順番を表している。また、照射密度は隣どうしのビームスポットが重ならない0%としている。なお、本実施の形態のレーザ光源は連続波（CW）を出射する半導体レーザであるため、パルス発振のレーザと違って駆動ミラー32a、32bが駆動している間もレーザ照射がされているが、移動に要している時間は非常に微小であるため、ここでは駆動ミラー32a、32bが止まった時に照射されるビームスポット位置のみ表示している。

【0029】従来のレーザ治療装置は図5のように照射する順番を横一列ずつ順番に走査していくため、熱による皮膚へのダメージが大きくなる。具体的には、初めの照射地点（数字の1番の位置）からすぐ隣の地点（数字の2番の位置）に続けて照射すると、初めの照射地点に与えられた熱の一部がその周囲に拡散している間に、すぐ隣の照射地点にレーザ光が照射されるため、初めの照射地点から拡散してきた熱量に対して、さらに新たな熱量が加わることとなる。その結果、その地点（ここでは数字の2番の位置）に加わる熱量は、予め設定した熱量よりも高い熱量を持つこととなるため、その地点における皮膚へのサーマルダメージが起り易くなる。

【0030】図6は本発明に基づいてスキヤニングを行なったときの図である。図6（a）はスキヤニング形状が正方形で4（ビームスポット）×4（ライン）の場合、図6（b）はスキヤニング形状が正方形で5（ビームスポット）×6（ライン）の場合を示している。

【0031】先ず、1ラインの左端のビームスポット位置（スポット位置）から照射を開始する。次の位置は、隣のビームスポット位置ではなく、図のように一つおきに照射を行なう。一つのラインに対して一つおきに照射ができなくなると、次に隣りのライン（2ライン）ではなく、一つ間をあけたライン（3ライン）から照射をするようにする。このときも1ラインと同じように左端から照射を始め、同一ライン上で隣り合うビームスポット位置に照射しないように照射していく。このように最初

に奇数ラインから照射を行ない、さらに同一ライン上では左端から一つおきに照射を初めていき、設定された照射範囲内においてすべての奇数ラインが一つおきに照射されると、今度は2ラインにもどり、同じように偶数ラインも左端から一つおきに照射を行う。

【0032】すべての偶数ラインが一つおきに照射されると、また最初に照射をした奇数ライン（1ライン）に戻り、残っているビームスポット位置を同じように奇数ラインから偶数ラインへと照射して、設定された照射領域上のすべてのビームスポット位置への照射を完了させる。

【0033】この他にも6×7、7×8、8×9のパターンが記憶されているが、数が増えているだけで、何れも同じ要領のスキヤニング方法となっている。

【0034】図7は照射形状が直線するとき（4×1、5×1、6×1のパターン）のスキヤニング方法を示している。照射領域形状が正方形のときと同じように、隣り合うビームスポット位置を避けて1つおきに照射を行なっていく。しかしながら、初めの照射地点は左端のビームスポット位置ではなく、その隣のビームスポット位置から始める。仮に左端のビームスポット位置から照射を始めてしまった場合、例えば4×1のパターン（図7（a））では2番目と3番目の照射地点が隣り合ってしまうからである。また、この他にも6×1、7×1、8×1のパターンがあるが、何れも同じようなスキヤニング方法となっている。

【0035】図8は照射形状が長方形（4×2、6×3のパターン）のスキヤニング方法を示している。これも前述したように隣り合うビームスポット位置を避けて、1つおきに照射を行なっていく。図8（a）のように4×2ラインしかない場合、両ラインとも左端からスキヤニングを始めてしまうと、4番目と5番目の照射地点が隣り合ってしまうため、図示のような順序にてスキヤニングを行なう。

【0036】図9は照射形状が六角形（4×3、6×5のパターン）のスキヤニング方法を示している。これも前述したように1つおきに照射を行なっていく。図9（a）の場合、3ラインとも左端から照射を開始してしまうと、6番目と7番目の照射地点が隣り合ってしまうため、図示のような順序にてスキヤニングを行なう。また、この他にも7×7のパターンがあるが、同じスキヤニング方法となっている。

【0037】こうしたレーザ照射のスポットの順序は、スキヤニング形状とその大きさのパターンに応じて予めメモリ52に記憶されており、スキャンコントロール51は設定されたスキヤニング形状から対応するパターンを制御部50を通じてメモリ52から呼び出し、この情報に基づいて各駆動モータ33a、33bを駆動制御する。なお、隣り合うところが無いように定められたスポット位置の順番は、パターンに応じて予め定めたものを

メモリ52に記憶しておく他、スキヤニング形状とその大きさ（さらに照射密度の設定情報）から求められるスポット位置の分布情報に基づき、こうした規則的な順番の配置を制御部50等が演算処理して定めるようにしても良い。

【0038】このように、隣り合うビームスポット位置、スキヤニングラインを連続して照射をすることがないため、一つの照射地点（ビームスポット位置）に対して十分な冷却時間を与えることができる。その結果、脱毛に必要な熱量は確保すると同時に余計な熱を加えることがないため、皮膚へのサーマルダメージが抑制できる。

【0039】以上、本実施の形態では半導体レーザを使用しているが、これに限るものではなく、レーザの種類、発振方法（連続波、パルス等）によらず使用することが可能である。

【0040】また、スキヤニング方法も全ての領域で隣り合うビームスポット位置を連続して照射しないように制御することができればこれに限るものではなく、例えば最初の照射地点を左端からではなく、右端からとしたり、奇数ラインからではなく偶数ラインから照射を行うことも可能である。

【0041】

【発明の効果】以上説明したように、本発明によれば、隣り合うスポット位置に連続してレーザ光を照射することがないため、十分な熱緩和時間を維持し、皮膚への過剰な熱供給を抑えてサーマルダメージを抑制することができる。

【図面の簡単な説明】

【図1】装置の外観図である。

【図2】ハンドピースユニットの詳細を示す図である。

【図3】コントロールパネルの詳細を示す図である。

【図4】制御系及び光学系を示す要部図である。

【図5】従来のスキヤニング方法を示す図である。

【図6】本発明における照射形状が正方形の場合のスキヤニング方法を示す図である。

【図7】本発明における照射形状が直線の場合のスキヤニング方法を示す図である。

【図8】本発明における照射形状が長方形の場合のスキヤニング方法を示す図である。

【図9】本発明における照射形状が六角形の場合のスキヤニング方法を示す図である。

【符号の説明】

30 ハンドピースユニット

40 コントロールパネル

50 制御部

51 スキャナーコントローラ

52 メモリ

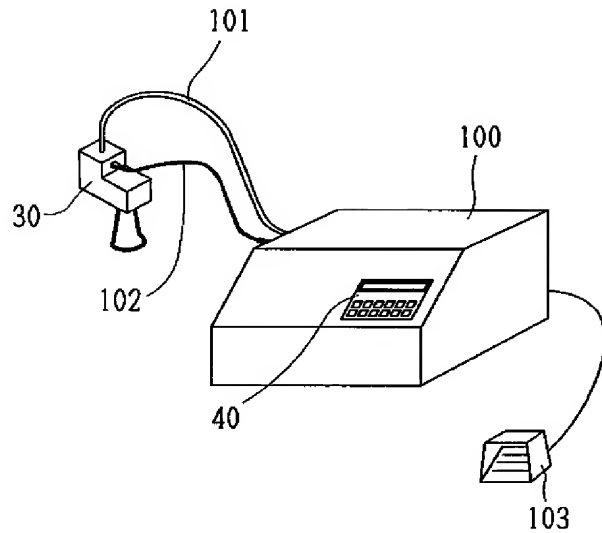
100 レーザ装置本体

101 光ファイバ

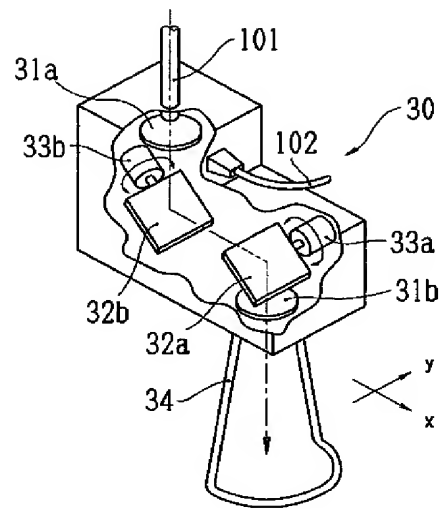
102 ケーブル  
103 フットスイッチ

104 レーザ光源  
105 エイミング光源

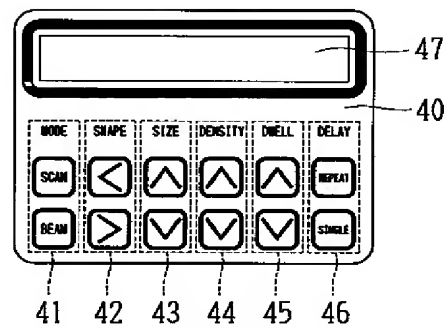
【図1】



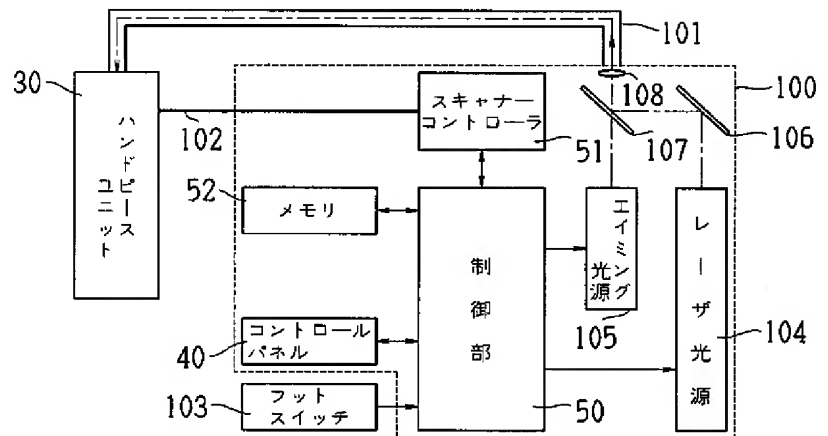
【図2】



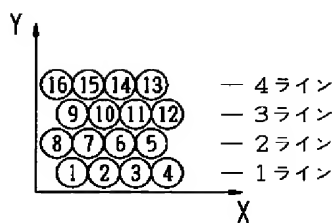
【図3】



【図4】

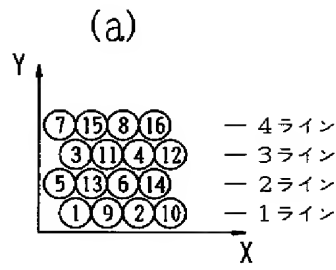


【図5】

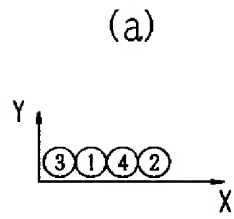




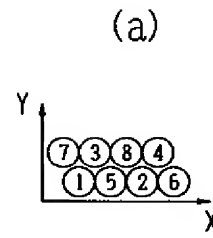
【図6】



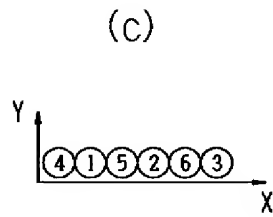
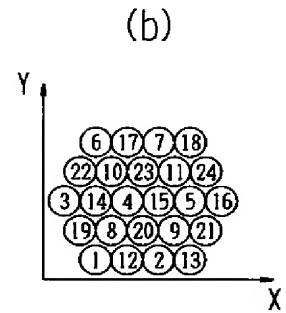
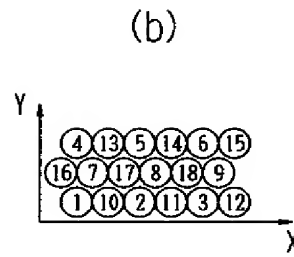
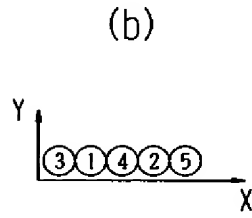
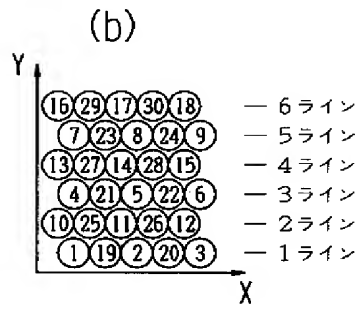
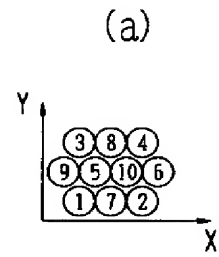
【図7】



【図8】



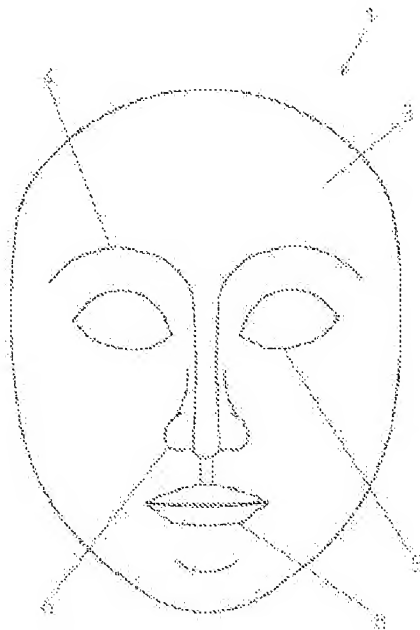
【図9】



**FAR INFRARED RAYS MASK****Publication number:** JP2001145520 (A)**Publication date:** 2001-05-29**Inventor(s):** HAMURA FUMIO**Applicant(s):** SHARION KK**Classification:****- international:** **A45D44/12; A61L15/58; A61N5/06; A45D44/00; A61L15/16; A61N5/06;** (IPC1-7): A45D44/12; A61L15/58; A61N5/06**- European:** A61N5/06C2**Application number:** JP19990367701 19991119**Priority number(s):** JP19990367701 19991119**Abstract of JP 2001145520 (A)**

**PROBLEM TO BE SOLVED:** To provide a mask which generates far infrared rays, tenders and activates the skin and can give off perfume.

**SOLUTION:** The inner face of a mask is made into a recessed face being approximately along the human face. Far infrared rays are generated by warming it. The mask is formed by adding a mineral or ceramic powder into a heat-resistant plastic type rubber for a mask material. The inner face of the mask is made into a face with a fine unevenness to obtain a face with water retention characteristics and a perfume is sprayed or the perfume is kneaded into a mask formable material to obtain a fragrant mask. A hygienic mask is formed by kneading an anti-fungus agent in the skin part of the inner face of the mask or the whole thickness part of the mask.



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(19)日本国特許庁 (J P)

(12) 公 開 特 許 公 報 (A)

(11)特許出願公開番号  
特開2001-145520  
(P2001-145520A)

(43)公開日 平成13年5月29日(2001.5.29)

(51)Int.Cl. <sup>7</sup>	識別記号	F I	テーマコード*(参考)
A 4 5 D 44/12		A 4 5 D 44/12	C 4 C 0 8 1
A 6 1 L 15/58		A 6 1 N 5/06	A 4 C 0 8 2
A 6 1 N 5/06		A 6 1 L 15/06	

審査請求 未請求 請求項の数4 書面 (全 4 頁)

(21)出願番号 特願平11-367701

(22)出願日 平成11年11月19日(1999.11.19)

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Fターム(参考) 4C081 AA09 AA12 BB03 BC02 CB042

CB051 CE01 CE02 CF22

DA01 DA02 DC03 DC12

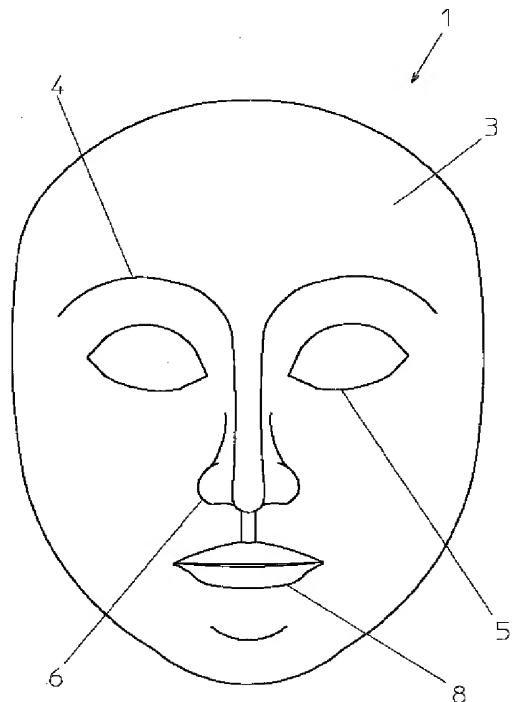
4C082 PA01 PC10 PG02 PJ21

(54)【発明の名称】 遠赤外線マスク

(57)【要約】 (修正有)

【課題】 遠赤外線を発生させ、肌を養生、活性化して、香りも楽しめるマスクを供する。

【解決手段】 マスクの内面を概ね人の顔に沿った凹面に成す。加温することで遠赤外線を発生する、鉱物又はセラミックスの粉末を、マスクの材料の耐熱プラスチック系ゴムに加えてマスクを形成する。マスクの内面を微細な凹凸の面に成して、保水性のある面を得て香水をつける、又はマスクを形成する材料に香料を練入して、香りのあるマスクを得る。マスクの内面表皮部分、又はマスク全肉部に、抗菌剤を練入して衛生的なマスクを形成する。



# 【特許請求の範囲】

【請求項1】 人の顔にかぶせて保温発汗を促し、美顔瘦身に用いるマスクにおいて、加温によって遠赤外線を発生する鉱物、セラミックスの粉末を練入した、耐熱プラスチック系ゴムでマスクを形成したことを、特徴とする遠赤外線マスク。

【請求項2】 前記、マスクの内面を微細な凹凸面に成して、保水性の有るマスク内面を、特徴とする請求項1の遠赤外線マスク。

【請求項3】 前記、マスクを形成する材料と、更に抗菌材料を使用して形成したことを、特徴とする請求項1の遠赤外線マスク。

【請求項4】 前記、マスクの表面を、人面様の凹凸と、人肌様の滑らかさに成して、人の顔のごとくマスク表面を、化粧可能に形成したことを特徴とする請求項1の遠赤外線マスク。

# 【発明の詳細な説明】

## 【0001】

【発明の属する技術分野】本発明は、入浴の時など、顔にかぶせて発汗を促すなどして、美顔瘦身に利用する化粧用具等に関するものである。

## 【0002】

【従来の技術】従来、美顔の目的で蒸しタオルを顔にかぶせて暖め肌を潤し、又遠赤外線を発生する泥を顔に塗って肌を暖め、細胞を活性化するなどが行われている。

## 【0003】

【発明が解決しようとする課題】従来の美顔瘦身の目的で入浴時などに、暖めたタオルを顔に当てて発汗を促し、肌を潤す場合は、タオルの温もりが冷めやすく、遠赤外線の発生なども期待できない。遠赤外線を発生する泥を顔に塗る等の方法も採られるが、この場合は自分自身で顔に塗って用いることは容易ではない。これらの課題を解決して、自分自身で容易に扱い得て、遠赤外線を発生させ、肌を養生、活性化する顔面用のマスクを供することを目的としたものである。

## 【0004】

【課題を解決するための手段】前述した課題を解決して上記目的を達成するために、本発明は次の技術的手段を講じたものである。請求項1は、マスクの内面を概ね人の顔に沿った凹面に成す。マスクを形成する材料は、加温することによって遠赤外線を発生する、鉱物又はセラミックスの粉末をマスクの材料に加えて、マスクを形成する。

【0005】請求項2は、マスクの内面を成形する型に予め微細な凹凸をつけてマスクを成形し、マスク内面を微細な凹凸の面に成して、保水性のある面を得る。請求項3は、マスクを成形する場合に、マスクの内面表皮部分、又はマスク全肉部に、抗菌剤を練入する。

【0006】請求項4は、マスクの外側表面を成形する型に、予め人顔の彫りの凹凸をつけてマスクを成形す

る。マスクの外側表面を形成する部分が人肌程度の硬度、滑らかさを持つように成して、普通に市販の化粧品でも、マスクに化粧して楽しむことを可能とする。

## 【0007】

【発明の実施の形態】本発明は、マスクの内面を概ね人の顔に沿うように成し、マスクを形成する材料は、加温して遠赤外線を発生する鉱物等の粉末を、材料に加えてマスクを形成し、入浴時などにお湯で暖めて顔にかぶせ、発生する遠赤外線が発汗を促し、細胞の活性化に寄与して肌を養生する。マスクの内面を成形する型に予め微細な凹凸をつけてマスクを成形して、マスク内面を微細な凹凸の面に成し、保水性のある面を得る。内面に香水を塗って保持、持続して香りを楽しむ。又化粧水を塗って置いて、間接的に顔の肌へ移して肌の養生をする。マスクを成形する場合に、マスクの内面表皮部分、又はマスク全肉部分に、抗菌剤を練入、又は塗るなどして抗菌効果を得て、衛生的なマスクを得る。マスクの外表面を成形する型に、予め人の面相の彫りをつけてマスクを成形し、外表面が人肌程度の硬度と、滑らかさを持つように成形して、マスクに化粧する楽しみ、化粧したマスクを仮面にして変身を楽しむことも可能にする。

## 【0008】

【実施例】以下、本発明を図面に示した実施例により説明する。「図1」、「図2」、「図3」に、実施例を示した。本発明は次の技術的手段を講じたものである。すなわち、遠赤外線マスク1の成形は、マスク内面2側、つまりマスク成形型の表側を概ね人の顔の凸面に成し、マスク表面3、つまりマスク成形型の内側を人の顔の形で凹面に成して、型を合わせた状態で全体に適宜隙間が出来るように型を作成する。加温することによって遠赤外線を発生する、鉱物を粉末にして、マスクの材料、実施例ではプラスチック系耐熱ゴムに練り加えて、前記型により成形して、遠赤外線マスク1を作る。

【0009】遠赤外線マスク1のマスク内面2を成形する型に予め微細な凹凸をつけて成形してマスク面に写し、マスク内面2を微細凹凸面9に成して保水性を得る。遠赤外線マスク1の成形で、マスク内面2の表皮部分、又は遠赤外線マスク1全肉部に、抗菌剤を練入して、抗菌性のある遠赤外線マスク1を形成する。遠赤外線マスク1のマスク表面3を成形する型は、人顔の彫りで凹形に仕上げて、マスクを成形する。又遠赤外線マスク1の外表面、マスク表面3は、その硬度を人肌程度の柔らかさにし、且つ人肌程度の滑らかさを持つように成形する。マスク表面3は、人肌様の柔らかさ、滑らかさを得、普通の市販の化粧品で化粧出来て、マスクを化粧して楽しむこと、化粧したマスクを仮面にして、遊び心で付けて楽しむことを可能とした。又遠赤外線マスク1の成形で、マスク内面2の表皮部分、又は遠赤外線マスク1全肉部に香料を練入し、当初より香りの有る遠赤外線マスク1を形成することも可能である。

【0010】

【発明の効果】遠赤外線マスクのマスク内面を人の顔の形に成形して、マスク成形材料は、加温することで遠赤外線を発生する鉱物を粉末にし、プラスチック系耐熱ゴムに練り加えて、遠赤外線マスクを形成する。遠赤外線マスクを予め、お風呂のお湯に浸けて暖めて置いて、入浴しながら顔に付ければ、マスクから発する遠赤外線

で、発汗や細胞の活性化など、肌の養生が期待できる。  
【0011】遠赤外線マスクのマスク内面に微細な凹凸をつけて成形し、マスク内面の微細な凹凸の面で、香料などの保持性を良くし、香料を付けて香りを楽しみながら入浴できる。同様に、マスク内面の微細な凹凸面に、化粧水を付けて用いれば、遠赤外線の効果と相まって肌の活性化、養生が期待できる。マスク内面の表皮部分、又はマスク全肉部に、抗菌剤を練入して、抗菌性のある常時衛生的なマスクを得ることが出来る。マスク表面を人顔の彫りに仕上げてマスクを成形し、その硬度を人肌程度の柔らかさに、且つ人肌程度の滑らかさに成して、

普通の市販の化粧品で化粧出来るように成して、マスク表面に化粧して楽しむこと、化粧したマスクを仮面のよう

【図面の簡単な説明】

【図1】本発明の遠赤外線マスクの正面図である。

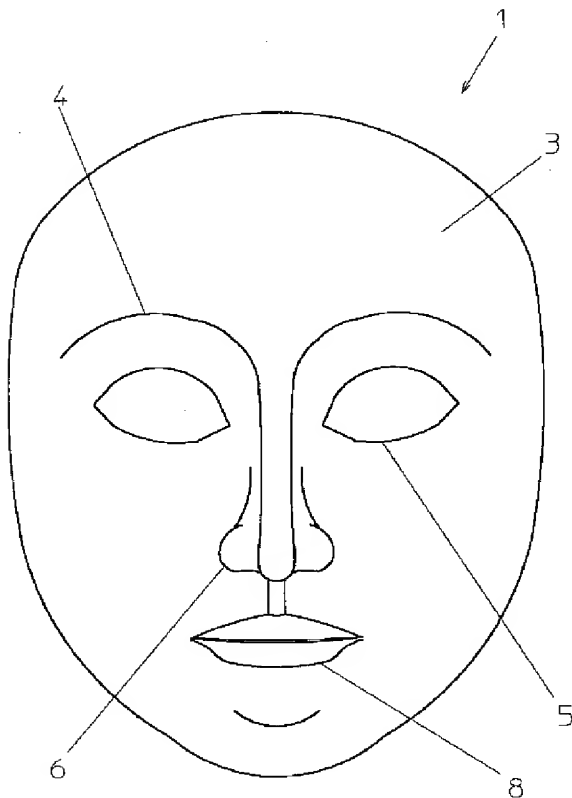
【図2】図1の左側面図である。

【図3】図1の左側断面図である。

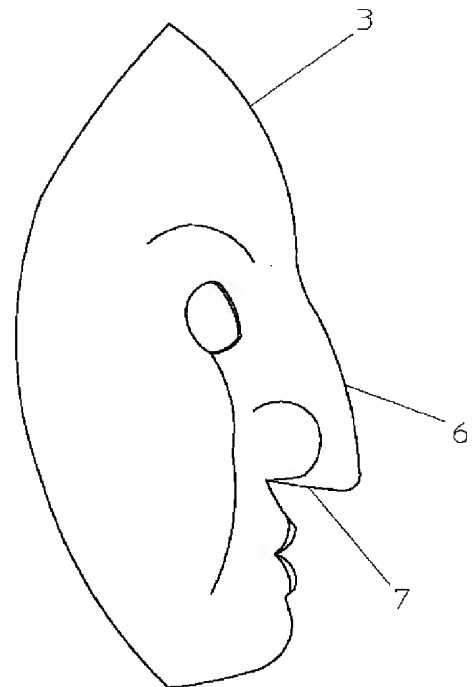
【符号の説明】

- 1 遠赤外線マスク
- 2 マスク内面
- 3 マスク表面
- 4 眉形
- 5 目形穴
- 6 鼻形
- 7 鼻穴
- 8 口ビル形
- 9 微細凹凸面

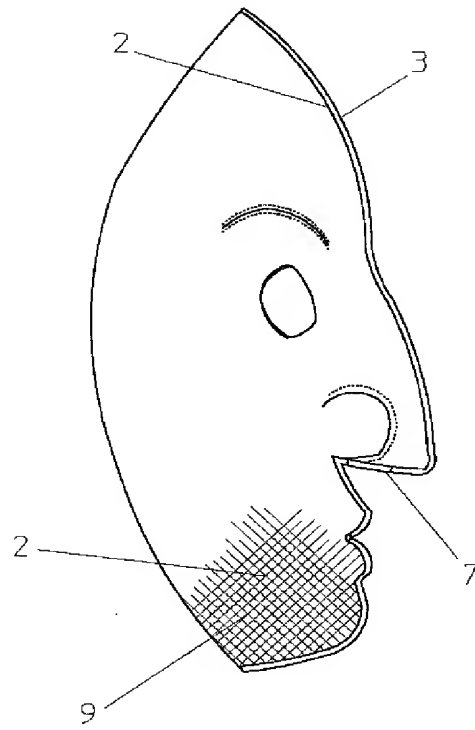
【図1】



【図2】



【図3】



**FACE TREATMENT MASK**

**Publication number:** JP2005027702 (A)

**Publication date:** 2005-02-03

**Inventor(s):** YAMAZAKI IWAO

**Applicant(s):** YA MAN LTD

**Classification:**

- **international:** A45D44/22; A45D44/12; A45D44/00; (IPC1-7): A45D44/22; A45D44/12

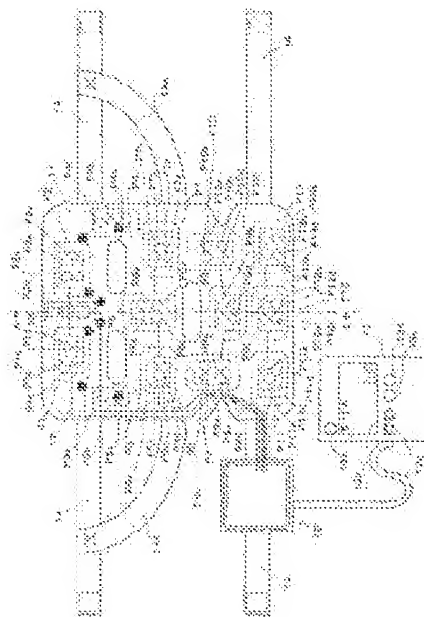
- **European:**

**Application number:** JP20030192809 20030707

**Priority number(s):** JP20030192809 20030707

Abstract of **JP 2005027702 (A)**

**PROBLEM TO BE SOLVED:** To provide a face treatment mask capable of treating the face of a person by utilizing the action of colors on a human body and irradiating with light beams of a plurality of colors selectively from light emitting diodes to effective points on the epidermis of the head or neck of the person. ; **SOLUTION:** In the mask for face treatment 10, visible light emitted from the light sources P1a, P1b, P1c, P1d, P2a, P2b, P2c and P2d of each light source part P1 and P2, etc. , penetrating a transparent or translucent face treatment mask body 11, is irradiated to the epidermis of the head and neck. The visible light radiated to the epidermis of the head and neck has prescribed color patterns, and because of the variety of color patterns, different treatment effects according to the patterns can be provided. ;  
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(19) 日本国特許庁 (JP)

(12) 公 開 特 許 公 報 (A)

(11) 特許出願公開番号

特開2005-27702

(P2005-27702A)

(43) 公開日 平成17年2月3日 (2005. 2. 3)

(51) Int. Cl. <sup>7</sup>

F 1

テーマコード (参考)

A 4 5 D 44/22

A 4 5 D 44/22

A

A 4 5 D 44/12

A 4 5 D 44/12

C

審査請求 未請求 請求項の数 11 O L (全 15 頁)

(21) 出願番号 特願2003-192809 (P2003-192809)  
(22) 出願日 平成15年7月7日 (2003. 7. 7)

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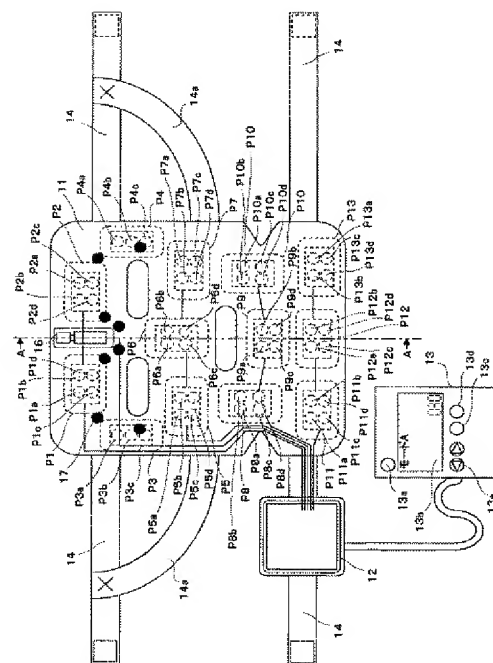
(54) 【発明の名称】 美顔用光マスク

(57) 【要約】

【課題】人体に及ぼす色彩の作用を利用して、頭頸部などの表皮にあるツボに対して、発光ダイオードによる複数の色の光を選択的に顔の表皮に照射することによって、トリートメントを行うことができる美顔用光マスクを提供することとする。

【解決手段】美顔用光マスク 10 において、各光源部 P 1、P 2…の光源 P 1 a、P 1 b、P 1 c、P 1 d、P 2 a、P 2 b、P 2 c、P 2 d…から出射された可視光は、透明または半透明の美顔用光マスク本体 1 1 を通過し、頭頸部の表皮に照射される。頭頸部の表皮に照射される可視光は、所定の色彩パターンを有しており、種々のパターンを備えることによって、異なるトリートメントの効果をすることができる。

【選択図】 図 1





**【特許請求の範囲】****【請求項1】**

顔面に装着されるマスク本体と、  
前記マスク本体の外面に所定のパターンで配設され、前記マスク本体を介して前記顔面に向けて異なる色相の光を出射する複数の光源部と、  
前記各光源部に電力を供給する電源と、  
前記電源から供給される電力を前記各光源部毎または前記複数の光源部からなるグループ毎に制御する光源制御部と  
を具備することを特徴とする美顔用光マスク。

**【請求項2】**

前記マスク本体が、透明または半透明であることを特徴とする請求項1記載の美顔用光マスク。

**【請求項3】**

前記マスク本体の前記光源部が配設された部分が、透明または半透明であることを特徴とする請求項1記載の美顔用光マスク。

**【請求項4】**

顔面に装着され、所定の位置に複数の開口部が設けられたマスク本体と、  
前記各開口部に嵌設され、前記顔面に向けて異なる色相の光を出射する複数の光源部と、  
前記各光源部に電力を供給する電源と、  
前記電源から供給される電力を前記各光源部毎または前記複数の光源部からなるグループ毎に制御する光源制御部と  
を具備することを特徴とする美顔用光マスク。

**【請求項5】**

前記マスク本体が、接触部材を介して顔面に装着されることを特徴とする請求項1乃至4いずれか1項記載の美顔用光マスク。

**【請求項6】**

前記美顔用光マスクが、前記マスク本体に一端が接続され、他端に面ファスナを備える固定用ベルトをさらに具備することを特徴とする請求項1乃至5いずれか1項記載の美顔用光マスク。

**【請求項7】**

前記光源部が、赤色、橙色、黄色、緑色、青色、紫色および白色の少なくとも一色を出射する光源を具備することを特徴とする請求項1乃至6のいずれか1項記載の美顔用光マスク。

**【請求項8】**

前記美顔用光マスクの前記複数の光源部から顔面に照射される可視光が、所定の色彩パターンを有して出射されることを特徴とする請求項1乃至7のいずれか1項記載の美顔用光マスク。

**【請求項9】**

前記マスク本体の内面の所定の位置に、顔面の表皮のツボを押圧する突起部をさらに具備することを特徴とする請求項1乃至8のいずれか1項記載の美顔用光マスク。

**【請求項10】**

前記マスク本体の内面の所定の位置に、前記頭頸部の表皮に振動を与える振動発生器をさらに具備することを特徴とする請求項1乃至9のいずれか1項記載の美顔用光マスク。

**【請求項11】**

前記マスク本体が、頭頸部に装着されるよう構成されたことを特徴とする請求項1乃至10のいずれか1項記載の美顔用光マスク。

**【発明の詳細な説明】****【0001】****【発明の属する技術分野】**

本発明は、発光ダイオードからの照射光を人体の表皮に照射することで得られるクロモセ

ラビ効果を利用した美顔用光マスクに関するもので、特に、頭頸部などの表皮にあるツボに対して、発光ダイオードランプによる複数の色の光を選択的に照射することによって、トリートメントを行うことができる美顔用光マスクに関する。

【0002】

【従来の技術】

従来、色彩が人体に心理的作用および生理的作用などを及ぼすことが確認されている。例えば、紫色は、血圧や心拍数を上昇させる循環機能の促進効果や食欲を抑えるなどの効果があり、青色は、身体的活動を抑え精神を沈静させるなどの効果などがある。また、緑色は、鎮静効果などがあり、黄色は、消化器系の働きを高める効果や精神的緊張を緩和させるなどの効果があり、赤色は、心拍数を上げ新陳代謝を促進する効果や心身をあたためるなどの効果がある。

【0003】

このような人体に及ぼす色彩の作用を利用して、患部の痛みの緩和などを行う健康器具が公開されている（例えば、特許文献1参照。）。

【0004】

【特許文献1】

特願平11-267179号公報

【0005】

【発明が解決しようとする課題】

本発明では、上記したような人体に及ぼす色彩の作用を利用して、頭頸部などの表皮にあるツボに対して、発光ダイオードランプによる複数の色の光を選択的に顔の表皮に照射することによって、トリートメントを行うことができる美顔用光マスクを提供すること目的とする。

【0006】

【課題を解決するための手段】

上記目的を達成するために、本発明の美顔用光マスクは、顔面に装着されるマスク本体と、前記マスク本体の外面に所定のパターンで配設され、前記マスク本体を介して前記顔面に向けて異なる色相の光を出射する複数の光源部と、前記各光源部に電力を供給する電源と、前記電源から供給される電力を前記各光源部毎または前記複数の光源部からなるグループ毎に制御する光源制御部とを具備することを特徴とする。

【0007】

この美顔用光マスクのマスク本体は、全体が透明または半透明、または、マスク本体の光源部が配設された部分のみが透明または半透明であることを特徴とする。

【0008】

この美顔用光マスクによれば、人体に及ぼす色彩の作用を利用して、顔面に発光ダイオードランプなどによる複数の色の光を選択的に顔の表皮に照射することによって、顔面のトリートメントを行うことができる。

【0009】

また、本発明の美顔用光マスクは、顔面に装着され、所定の位置に複数の開口部が設けられたマスク本体と、前記各開口部に嵌設され、前記顔面に向けて異なる色相の光を出射する複数の光源部と、前記各光源部に電力を供給する電源と、前記電源から供給される電力を前記各光源部毎または前記複数の光源部からなるグループ毎に制御する光源制御部とを具備することを特徴とする。ここで、光源部の光出射面には、透明または半透明の部材が装着されてもよい。

【0010】

この美顔用光マスクによれば、人体に及ぼす色彩の作用を利用して、顔面に発光ダイオードランプなどによる複数の色の光を選択的に顔の表皮に照射することによって、顔面のトリートメントを行うことができる。

【0011】

また、本発明の美顔用光マスクは、前記マスク本体が、接触部材を介して顔面に装着され

ることを特徴とする。

【0012】

この美顔用光マスクによれば、マスク本体と顔面との間に接触部材を備えることで、各光源部と顔面との間の距離が増加する。これによって、接触部材が備えられない場合と比べて、光源部から出射された可視光を顔面の広範囲に照射することができ、光源部の数を減少させることができる。

【0013】

また、本発明の美顔用光マスクは、前記美顔用光マスクが、前記マスク本体に一端が接続され、他端に面ファスナを備える固定用ベルトをさらに具備することを特徴とする。

【0014】

さらに、本発明の美顔用光マスクは、前記光源部が、赤色、橙色、黄色、緑色、青色、紫色および白色の少なくとも一色を出射する光源を具備することを特徴とする。

【0015】

この美顔用光マスクによれば、光源部が、赤色、橙色、黄色、緑色、青色、紫色および白色の少なくとも一色を出射する光源を具備し、各色が顔面に照射されることで、各色も持つトリートメント効果を得ることができる。

【0016】

また、本発明の美顔用光マスクは、前記美顔用光マスクの前記複数の光源部から顔面に出射される可視光が、所定の色彩パターンを有して出射されることを特徴とする。

【0017】

この美顔用光マスクによれば、所定の色彩パターンを有した光が顔面に照射されることで、顔面の各部分に最適な色相の光を照射することができ、顔面全体に渡って最適なトリートメントを行うことができる。

【0018】

また、本発明の美顔用光マスクは、前記マスク本体の内面の所定の位置に、顔面の表皮のツボを押圧する突起部をさらに具備することを特徴とする。さらに、前記マスク本体の内面の所定の位置に、前記頭頸部の表皮に振動を与える振動発生器をさらに具備することを特徴とする。

【0019】

この美顔用光マスクによれば、動的な刺激が顔面に付与され、可視光を照射することで得られるトリートメントの効果に加えて、マッサージ効果を得ることができる。

【0020】

また、マスク本体は、顔面以外に、頸部にも装着されるよう構成されてもよい。これによって、顔面のトリートメントに加えて、しわやたるみなどが生じやすい頸部のトリートメントを行うことができる。

【0021】

【発明の実施の形態】

以下、本発明の一実施の形態について図を参照して説明する。

【0022】

図1には、本発明の一実施の形態に係る美顔用光マスク10の頭頸部の表皮接触面側からの平面図、図2には、図1に示した美顔用光マスク10のA-A断面図を示す。また、図3は、美顔用光マスク10を頭頸部に装着したときの外観を示す図である。ここで、頭頸部とは、顔面および頸部を意味する。

【0023】

美顔用光マスク10は、美顔用光マスク本体11と、この美顔用光マスク本体11の外側に配設された光源部P1、P2…と、各光源部P1、P2…と電氣的に接続された光源制御部12と、光源制御部12と制御信号を交信するリモートコントローラ13と、美顔用光マスク本体11に一端が接続された固定用ベルト14で主に構成されている。

【0024】

美顔用光マスク本体11は、透明または半透明な樹脂で形成され、例えば、アクリル樹脂

、ポリエチレンなどが用いられる。また、美顔用光マスク本体11には、頭頸部の眼窩部および口部に対応する部分に開口部が形成されている。なお、美顔用光マスク本体11は、透明または半透明で、ヤング率の比較的小さい柔軟な樹脂で形成されてもよい。また、美顔用光マスク本体11は、頭頸部の表皮を覆うように構成されるものに限らず、顔面部の表皮のみを覆う構成、頸部の表皮のみを覆う構成でもよい。

【0025】

また、美顔用光マスク本体11は、光源部P1、P2…が配設される部分のみが、透明または半透明な樹脂で形成されてもよい。そして、それ以外の部分を、例えば、光を透過しない材料で構成されてもよい。これによって、頭頸部の表皮に照射された光の反射光の外部への放出を抑制することができる。

【0026】

光源部P1、P2…は、赤色、橙色、黄色、緑色、青色、紫色および白色の光をそれぞれ発生する7種の発光ダイオードランプのいずれか少なくとも1つが選択的に設置された光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…を備えている。光源部P1、P2…に備えられる光源の数は、必要に応じて適宜に決めることができ、図1に示した美顔用光マスク10の光源部P1、P2…には、3つまたは4つの光源が備えられている。

【0027】

なお、光源部P1、P2…に備えられる光源の数は、これに限られるものではなく、5つ以上の光源を備えてもよく、光源の配置構成も適宜に決めることができる。また、光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…は、異なる色を発光する複数の発光ダイオードランプを光源部P1、P2…の表面に分散させて構成されてもよい。また、光の三原色である赤色、緑色、青色の発光ダイオードランプを各光源に備え、それらの色を混色することで、他の色を構成してもよい。さらに、光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…として、1つの発光ダイオードランプで複数の色を発光することができる発光ダイオードランプを用いてもよい。

【0028】

また、光源部P1、P2…は、美顔用光マスク10の頭頸部の表皮に接触する内側面に対向する外側面に、頭頸部の表皮の各ツボに対応するよう配設されている。ここで、光源部P1、P2…は、例えば、美顔用光マスク10の外側面に着脱可能に取り付けられてもよい。各光源部P1、P2…の光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…を構成する発光ダイオードランプは、光源制御部12と電気的に接続されている。

【0029】

また、光源部P1、P2…は、頭頸部の表皮の各ツボに対応するよう美顔用光マスク本体11に複数の開口部を設け、それらの開口部に嵌設されてもよい。この場合、光源部P1、P2…の光出射面には、透明または半透明の部材が装着されてもよい。

【0030】

光源制御部13は、電気的に接続されたリモートコントローラ13からの制御信号に基づいて、光源部P1、P2…の発光ダイオードランプを制御するもので、各光源部P1、P2…の各発光ダイオードランプと電気的に接続されている。

【0031】

また、光源制御部12は、図4に示すように、入力部12a、演算部12b、記憶部12c、出力部12dを有している。ここで、入力部12aには、リモートコントローラ13からの制御信号などが入力される。記憶部12cには、例えば、各トリートメントモードに対応したプログラムやデータなどが格納される。演算部12bは、記憶部12cに格納されたプログラムやデータなどを用いて各種の演算処理を行う。出力部12dでは、演算部12bや記憶部12cの情報に基づいて、光源部P1、P2…やリモートコントローラ13などに制御信号を出力する。

【0032】

なお、光源制御部12とリモートコントローラ13との間の情報の通信は、配線を介して電気的に行うものに限らず、電波などを介して無線で行うこともできる。光源制御部13は、美顔用光マスク10を頭頸部に取り付ける際、取り付けの妨げにならない、例えば、固定用ベルト14の所定の位置などに取り付けられる。また、光源制御部12は、リモートコントローラ13に組み込まれて設置されてもよい。

#### 【0033】

リモートコントローラ13には、主電源13a、表示部13b、機能選択ボタン13c、確定ボタン13d、選択ボタン13eなどが備えられている。主電源13aは、電源をオン／オフするもので、機能選択ボタン13cは、設定する機能項目を選択するもので、選択される機能には、例えば、トリートメントモード機能、タイマ設定機能、マニュアル機能などがある。

#### 【0034】

選択ボタン13eは、機能選択ボタン13cで選択された機能項目内のさらに詳細な機能を選択または設定するもので、例えば、機能選択ボタン13cでトリートメントモード機能が選択された場合には、予め設定された各種トリートメントモードから選択ボタン13eを押すことによって、好みのトリートメントモードを選択することができる。また、機能選択ボタン13cで、例えば、タイマ設定機能が選択された場合には、選択ボタン13eを押して、表示部13bに表示される設定時間の数値を見ながらトリートメントの時間を設定することができる。さらに、機能選択ボタン13cで、例えば、マニュアル機能が選択された場合には、可視光を射出する光源部P1、P2…の設定、発光ダイオードランプから射出される可視光の射出強度の設定などを、選択ボタン13eを押すことで任意に選択することができる。確定ボタン13dは、機能選択ボタン13cおよび選択ボタン13eで選択または設定されたトリートメントモードを確定するためのものである。

#### 【0035】

固定用ベルト14は、帯形状を有し、布、樹脂、ゴムなどで形成されている。図1に示すように、2本の固定用ベルト14のそれぞれの一端が、美顔用光マスク本体11の左端の縁部に接続されている。また、2本の固定用ベルト14の間には、一端が美顔用光マスク本体11の左端の縁部に接続され、他端が2本の固定用ベルト14の一方に接続された補助用固定用ベルト14aが備えられている。さらに、2本の固定用ベルト14のそれぞれの他端には、面ファスナが設けられている。一方、美顔用光マスク本体11の右端の縁部にも、美顔用光マスク本体11の左端の縁部と同様に、2本の固定用ベルト14および補助用固定用ベルト14aが接続されており、2本の固定用ベルト14のそれぞれの他端には、面ファスナが設けられている。

#### 【0036】

美顔用光マスク本体11を頭頸部に装着する際、左端の縁部に接続された固定用ベルト14の他端部に設けられた面ファスナと、右端の縁部に接続された固定用ベルト14の他端部に設けられた面ファスナとを接続することで、美顔用光マスク本体11は頭頸部に装着される。

#### 【0037】

ここで、図1に示すように、美顔用光マスク10の美顔用光マスク本体11には、さらに、振動発生器16、ツボ押圧用突起部17を備えることもできる。

#### 【0038】

振動発生器16は、美顔用光マスク本体11の頭頸部の表皮と接触する面の光源部P1と光源部P2との間に対応する位置に配設され、光源制御部12と電気的に接続されている。振動発生器16は、それ自身が振動し、頭頸部の表皮に振動を与え、トリートメントを行うものである。振動発生器16を設けた場合には、リモートコントローラ13の機能選択ボタン13cによって選択される機能として、さらに、振動モード機能が付加される。振動モード機能には、例えば、振動のオン・オフ、振動の強弱などを設定するモードなどが予め設定されている。

#### 【0039】

ツボ押圧用突起部17は、ゴム、樹脂などで形成された突起物で、美顔用光マスク本体11の頭頸部の表皮と接触する面に配設される。図1に示された美顔用光マスク10では、ツボ押圧用突起部17は、眼窩部に対応させて開口された開口部の上部側に開口部に沿って配設されている。なお、ツボ押圧用突起部17の配設される位置は、この部分に限られるものではなく、他の頭頸部におけるツボの位置に対応させて任意に配設される。ツボ押圧用突起部17は、例えば、美顔用光マスク本体11の頭頸部の表皮と接触する面に、着脱可能に取り付けられてもよく、または、美顔用光マスク本体11に一体的に形成されてもよい。

#### 【0040】

(美顔用光マスク10の作用)

美顔用光マスク10において、各光源部P1、P2…の光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…から出射された可視光は、透明または半透明の美顔用光マスク本体11を通過し、頭頸部の表皮に照射される。以下に、図4および5を参照して、この頭頸部の表皮に可視光を照射する作用の一例を説明する。ここで、図5には、美顔用光マスク10における制御に関する流れ図が示されている。

#### 【0041】

主電源13aがオンされ、リモートコントローラ13によって、トリートメントモードが設定されると、光源制御部12の入力部12aにその設定された情報が入力される(ステップS30)。入力部12aは、その入力された情報を演算部12bに出力する(ステップS30)。

#### 【0042】

演算部12bでは、入力部12aから出力された情報に基づいて、振動モードがオンされた否かを判定する(ステップS31)。

#### 【0043】

振動モードがオンされたことが演算部12bによって判定されると(ステップS31のYes)、演算部12bは、要求された振動モードの情報に対応するプログラムを記憶部12cから読み出し、そのプログラムを実行する(ステップS32)。そして、実行したプログラムに対応して振動発生器16を制御するための制御信号を出力部12dに出力する(ステップS32)。出力部12dは、その制御信号を振動装置16に出力し、振動発生器16を作動させる(ステップS32)。

#### 【0044】

振動モードがオンされていないことが演算部12bによって判定されると(ステップS31のNo)、演算部12bは、要求されたトリートメントモードの情報に対応するプログラムを記憶部12cから読み出し、そのプログラムを実行する(ステップS33)。そして、実行したプログラムに対応して各光源部P1、P2…を制御するための制御信号を出力部12dに出力する(ステップS33)。出力部12dは、その制御信号を対応する光源部P1、P2…に出力し、光源部P1、P2…の光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…から可視光を出射させる(ステップS33)。

#### 【0045】

さらに、演算部12bでは、入力部12aから出力された情報に基づいて、トリートメント設定時間に達したか否かを判定する(ステップS34)。

#### 【0046】

トリートメント設定時間に達していないことが演算部12bによって判定されると(ステップS34のNo)、演算部12bは、トリートメント設定時間に達したか否かの判定を繰り返し行う。

#### 【0047】

トリートメント設定時間に達したことが演算部12bによって判定されると(ステップS34のYes)、演算部12bは、トリートメントを終了するための制御信号を出力部12dに出力する。出力部12dは、その制御信号を光源部P1、P2…に出力し、光源部P1、P2…の光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d

…からの可視光の出射を停止させる。なお、振動モードがオンされたことが演算部12bによって判定された場合には、演算部12bは、振動発生器16の動作を停止させるための制御信号を出力部12dに出力し、出力部12dは、その制御信号を振動装置16に出力し、振動発生器16の動作を停止させる。

【0048】

ここでは、振動発生器16を備えた美顔用光マスク10における作用を示したが、振動発生器16を備えない美顔用光マスク10では、ステップS31およびステップS32の工程は削除される。

【0049】

次に、美顔用光マスク10の頭頸部の表皮と接触する内側面に、接触部材40を取り付けた実施の形態を図6に示す。また、図7には、接触部材40が取り付けられた美顔用光マスク10が装着されたときの美顔用光マスク10のA-A断面図を示す。

【0050】

接触部材40は、例えば、スポンジなどの柔軟な部材で形成され、図6に示すように、美顔用光マスク本体11の内側面の外縁部に配設されている。

【0051】

美顔用光マスク本体11と頭頸部の表皮との間に接触部材40を備えることで、各光源部P1、P2…の光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…と頭頸部の表皮との間の距離が増加する。これによって、接触部材40が備えられない場合と比べて、光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…から出射された可視光を頭頸部の表皮の広範囲に照射することができ、光源の数を減少させることができる。

【0052】

(トリートメントモード例)

次に、図1を参照してトリートメントモードについて説明する。ここで、予め設定されたトリートメントモードは、(1)顔痩せモード、(2)美白モード、(3)脂性によるニキビ解消モード、(4)老化防止モード、(5)赤ら顔改善モード、(6)乾燥肌防止モード、(7)過敏肌改善モード、(8)便秘によるニキビ解消モードである。なお、ここでは、上記モードが予め設定されているが、これらのモードに限られるものではなく、他のモードも設定することができる。

【0053】

図1には、上記トリートメントモードに対応して可視光を頭頸部の表皮へ照射する各光源部P1、P2…配置構成が示されている。光源部P1、P2は前頭部に対応する位置に、光源部P3、P4は前頭部から頬骨部にかけての顔の輪郭に沿った部分に対応する位置に、光源部P5、P7は眼窩部の下部から頬骨部に対応する位置に、光源部P6は鼻部に対応する位置に配設されている。また、光源部P8、P10は頬部に対応する位置に、光源部P9はオトガイ部に対応する位置に、光源部P12は頸部の輪状軟骨付近に対応する位置に、光源部P11、P13は頸部の光源部P12に隣り合う位置に配設されている。

【0054】

なお、光源部P1、P2…は、美顔用光マスク本体11の頭部から頸部に向かう中心線に対して線対称に構成されているので、図1に示された光源部P1、P2…の内、線対称に対して一方の側(図1の美顔用光マスク本体11の左側)について、各光源部P1、P3、P5…における光源P1a、P1b、P1c、P1d、P3a、P3b、P3c…の配置構成の一例を説明する。

【0055】

光源部P1は、4つの光源P1a、P1b、P1c、P1dで構成され、各光源P1a、P1b、P1c、P1dには、赤色の発光ダイオードランプおよび橙色の発光ダイオードランプが設置されている。

【0056】

光源部P3は、3つの光源P3a、P3b、P3cで構成され、各光源P3a、P3b、

P 3 c には、赤色の発光ダイオードランプおよび紫色の発光ダイオードランプが設置されている。

【 0 0 5 7 】

光源部 P 5 は、4 つの光源 P 5 a、P 5 b、P 5 c、P 5 d で構成されている。光源 P 5 a には、赤色の発光ダイオードランプおよび橙色の発光ダイオードランプが、光源 P 5 b には、赤色の発光ダイオードランプおよび黄色の発光ダイオードランプが設置されている。また、光源 P 5 c には、赤色の発光ダイオードランプおよび橙色の発光ダイオードランプが、光源 P 5 d には、赤色の発光ダイオードランプ、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。

【 0 0 5 8 】

光源部 P 6 は、4 つの光源 P 6 a、P 6 b、P 6 c、P 6 d で構成されるが、光源 P 6 a と光源 P 6 b、光源 P 6 c と光源 P 6 d に設置される発光ダイオードランプの配置構成は同一なので、光源 P 6 a および光源 P 6 c の配置構成について示す。光源 P 6 a には、赤色の発光ダイオードランプおよび黄色の発光ダイオードランプが、光源 P 6 c には、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。

【 0 0 5 9 】

光源部 P 8 は、4 つの光源 P 8 a、P 8 b、P 8 c、P 8 d で構成されている。光源 P 8 a には、赤色の発光ダイオードランプおよび橙色の発光ダイオードランプが、光源 P 8 b には、赤色の発光ダイオードランプ、橙色の発光ダイオードランプ、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。また、光源 P 8 c には、赤色の発光ダイオードランプ、橙色の発光ダイオードランプおよび青色の発光ダイオードランプが、光源 P 8 d には、赤色の発光ダイオードランプ、橙色の発光ダイオードランプ、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。

【 0 0 6 0 】

光源部 P 9 は、4 つの光源 P 9 a、P 9 b、P 9 c、P 9 d で構成されるが、光源 P 9 a と光源 P 9 b、光源 P 9 c と光源 P 9 d に設置される発光ダイオードランプの配置構成は同一なので、光源 P 9 a および光源 P 9 c の配置構成について示す。光源 P 9 a には、赤色の発光ダイオードランプおよび黄色の発光ダイオードランプが、光源 P 9 c には、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。

【 0 0 6 1 】

光源部 P 1 1 は、4 つの光源 P 1 1 a、P 1 1 b、P 1 1 c、P 1 1 d で構成されている。光源 P 1 1 a には、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが、光源 P 1 1 b には、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。また、光源 P 1 1 c には、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが、光源 P 1 1 d には、橙色の発光ダイオードランプ、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。

【 0 0 6 2 】

光源部 P 1 2 は、4 つの光源 P 1 2 a、P 1 2 b、P 1 2 c、P 1 2 d で構成されるが、光源 P 1 2 a と光源 P 1 2 b、光源 P 1 2 c と光源 P 1 2 d に設置される発光ダイオードランプの配置構成は同一なので、光源 P 1 2 a および光源 P 1 2 c の配置構成について示す。光源 P 1 2 a には、赤色の発光ダイオードランプ、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが、光源 P 1 2 c には、赤色の発光ダイオードランプ、橙色の発光ダイオードランプ、黄色の発光ダイオードランプおよび青色の発光ダイオードランプが設置されている。

【 0 0 6 3 】

なお、各光源部 P 1、P 2…には、各色相の波長を有する白色の発光ダイオードランプを併設させてもよい。さらに、各光源部 P 1、P 2…には、ストレスや精神疲労に効果的な緑色の発光ダイオードランプを併設させてもよい。

【 0 0 6 4 】

(照射パターン)



次に、図1、図8および図9を参照して、上記した各光源部P1、P2…の光源P1a、P1b、P1c、P1d、P2a、P2b、P2c、P2d…から出射された可視光によって形成される(1)～(8)の各モードの照射パターンについて説明する。

【0065】

図8には、可視光が照射される頭頸部の表皮上の区分された領域50、51、52、…、64が示されている。

【0066】

領域50は、左右の眼窩部間から前頭部にかけた部分、領域51は、前頭部のほぼ全体の部分、領域52は、前頭部から頬骨部にかけた顔の輪郭に沿った部分である。また、領域53は、眼窩部の下方で眼窩部に沿った部分、領域54は、眼窩下部の部分、領域55は、鼻部に沿った鼻孔の脇の部分、領域56は、鼻部の部分、領域57は、頬部の部分である。また、領域58は、頬部にかけた顔の輪郭に沿った部分、領域59は、頬部と口部との間の凹部の部分、領域60は、鼻部と口部との間の口部に沿った部分、領域61は、口部の下部で口部に沿った部分である。領域62は、オトガイ部の部分、領域63は、頸部の輪状軟骨付近の部分、領域64は、頸部の領域63に隣接する部分である。

【0067】

図9には、可視光が照射される頭頸部の表皮上の区分されたツボの領域70、71、72、…、78が示されている。

【0068】

領域70は上星、領域71は糸竹空、領域72は攒竹、領域73は三焦経上、領域74は迎香、領域75は禾りょう、領域76は地倉、領域77は大腸経上、領域78は星状神経節である。

【0069】

(1) 顔痩せモード

顔痩せモードでは、領域50に橙色、領域52に紫色、領域54、55、60、61に黄色、領域58、62、64に青色の光が照射される。

【0070】

領域50に橙色の光を照射することによって、むくみを抑制し、排泄を促すことができる。領域52に紫色の光を照射することによって、肌に弾力を与えることができる。領域54、55、60、61に黄色の光を照射することによって、胃の働きを整え、食べ過ぎを防ぐことができる。領域58、62、64に青色の光を照射することによって、静脈を流れる血液やリンパ管を流れるリンパ液の循環を促進することができる。

【0071】

(2) 美白モード

美白モードでは、領域50、63に橙色、領域54、61に黄色、領域55、59、64に青色の光が照射される。

【0072】

領域50に橙色の光を照射することによって、体を活性化し、出産や婦人科系のトラブルなどによって形成されたシミなどを改善することができる。また、領域63に橙色の光を照射することによって、痩せ型の人に形成されるシミなどを改善することができる。領域54、61に黄色の光を照射することによって、肥満型の人に形成されるシミなどを改善することができる。さらに、各臓器の活性化を図ることができる。領域55、59、64に青色の光を照射することによって、皮膚機能が改善され、顔色、くすみの改善をすることができる。

【0073】

(3) 脂性によるニキビ解消モード

脂性によるニキビ解消モードでは、領域51、56に橙色、領域53に赤色、領域54、55、59、60、61、62、63、64に黄色の光が照射される。

【0074】

領域51、56に橙色の光を照射することによって、皮脂腺が多くて皮脂詰りになりやす

い場所を深部から温めることにより汚れを排出しやすくすることができる。また、領域51に橙色の光を照射することによって、生理前のニキビを予防することができる。領域53に赤色の光を照射することによって、ブツブツが出やすい肌を改善することができる。領域54、55、59、60、61、62、63、64に黄色の光を照射することによって、ニキビを解消、予防することができる。

【0075】

(4) 老化防止モード

老化防止モードでは、領域51、52、53、60、61に赤色、領域57、58に橙色、領域63、64に青色の光が照射される。

【0076】

領域51、52、53、60、61に赤色の光を照射することによって、照射部が穏やかに刺激され、血液循環を促進することができる。これによって、照射部のしわ、たるみを防止することができる。また、領域53に赤色の光を照射することによって、小腸経を刺激し、肌へ栄養を行き渡らせることができる。領域57、58に橙色の光を照射することによって、筋肉を活性化し、たるみなどを防止することができる。領域63、64に青色の光を照射することによって、静脈を流れる血液やリンパ管を流れるリンパ液の循環を促進し、しわ、たるみを防止することができる。

【0077】

(5) 赤ら顔改善モード

赤ら顔改善モードでは、領域50に橙色、領域53、57、58、59に赤色、領域54、55、60、61に黄色の光が照射される。

【0078】

領域50に橙色の光を照射することによって、照射部が活性化され、赤ら顔を抑制することができる。領域53、57、58、59に赤色の光を照射することによって、照射部が活性化されるとともに、小腸経が刺激され、肌へ栄養を行き渡らせることができる。領域54、55、60、61に黄色の光を照射することによって、肌を強化することができる。

【0079】

(6) 乾燥肌防止モード

乾燥肌防止モードでは、領域51、53に赤色、領域52に紫色、領域54、55、56、59、60、61、62に黄色、領域57、58に橙色、領域64に青色の光が照射される。

【0080】

領域51、53に赤色の光を照射することによって、照射部が活性化され、肌のかさつきを抑えることができる。領域52に紫色の光を照射することによって、肌に弾力を与えることができる。領域54、55、56、59、60、61、62に黄色の光を照射することによって、各臓器の働きを活性化し、水分バランスを改善することができる。領域57、58に橙色の光を照射することによって、照射部が活性化され、肌のかさつきを抑えることができる。領域64に青色の光を照射することによって、静脈を流れる血液やリンパ管を流れるリンパ液の循環を促進することができる。

【0081】

(7) 過敏肌改善モード

過敏肌改善モードでは、領域70、72、78に橙色、領域74、76に黄色の光が照射される。

【0082】

領域70、72に橙色の光を照射することによって、過敏肌の肌質を改善することができる。また、領域78に橙色の光を照射することによって、色白の人における過敏肌の肌質を改善することができる。領域74、76に黄色の光を照射することによって、各臓器の機能強化や神経組織の正常化を図ることができる。

【0083】

#### ( 8 ) 便秘によるニキビ解消モード

便秘によるニキビ解消モードでは、領域 7 1、7 3 に紫色、領域 7 4、7 5、7 7 に青色の光が照射される。

##### 【 0 0 8 4 】

領域 7 1、7 3 に紫色の光を照射することによって、リンパ管を流れるリンパ液の流れを促進し、体内の老廃物や毒素を除去することで、ニキビを解消、予防することができる。領域 7 4、7 5、7 7 に青色の光を照射することによって、便秘を改善し、ニキビを解消、予防することができる。

##### 【 0 0 8 5 】

上記したように、本発明の美顔用光マスクによれば、透明または半透明の美顔用光マスク本体を介して光源部から所定の色の光を所定の頭頸部の表皮に照射して、表皮のトリートメントを行うことができる。また、美顔用光マスクは、頭頸部の表皮のほぼ全体を覆うことができるので、一括して頭頸部の表皮のほぼ全体を自動的にトリートメントすることができる。

##### 【 0 0 8 6 】

また、美顔用光マスクの 1 つの光源部には、異なる色を照射する複数の光源を備えることができるので、種々のトリートメントモードを設定することができる。さらに、光源部は、美顔用光マスク本体と着脱可能に取り付けることができるため、所定の色の光源を有する光源部を任意に移動することもできる。

##### 【 0 0 8 7 】

また、美顔用光マスクに振動発生器、ツボ押圧用突起部を備えることで、動的な刺激が頭頸部の表皮に付与され、可視光を照射することで得られるトリートメントの効果に加えて、マッサージ効果を得ることができる。

##### 【 0 0 8 8 】

##### 【発明の効果】

本発明の美顔用光マスクによれば、人体に及ぼす色彩の作用を利用して、頭頸部などの表皮にあるツボに対して、発光ダイオードランプによる複数の色の光を選択的に顔の表皮に照射することによって、トリートメントを行うことができる。

##### 【図面の簡単な説明】

【図 1】本発明の一実施の形態に係る美顔用光マスクの頭頸部の表皮接触面側からの平面図。

【図 2】図 1 に示された美顔用光マスクの A-A 断面図。

【図 3】美顔用光マスクを頭頸部に装着したとき外観を示す図。

【図 4】光源制御部の構成を示す図。

【図 5】美顔用光マスクにおける制御に関する流れ図。

【図 6】美顔用光マスクの他の実施の形態を示す平面図。

【図 7】図 6 に示された美顔用光マスクを頭頸部に装着した状態を示す美顔用光マスクの断面図。

【図 8】可視光が照射される頭頸部の表皮上の領域の区分を示す図。

【図 9】可視光が照射される頭頸部の表皮上のツボの領域の区分を示す図。

##### 【符号の説明】

1 0…美顔用光マスク

1 1…美顔用光マスク本体

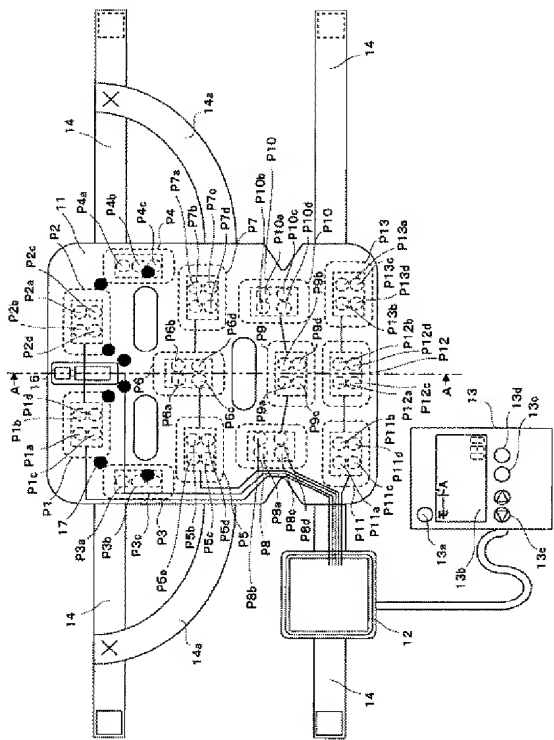
1 2…光源制御部

1 3…リモートコントローラ

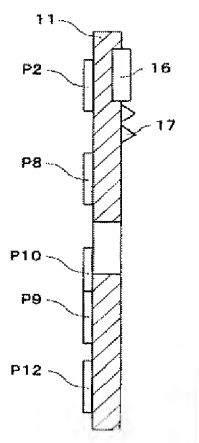
1 4…固定用ベルト

P 1、P 2…、P 1 3…光源部

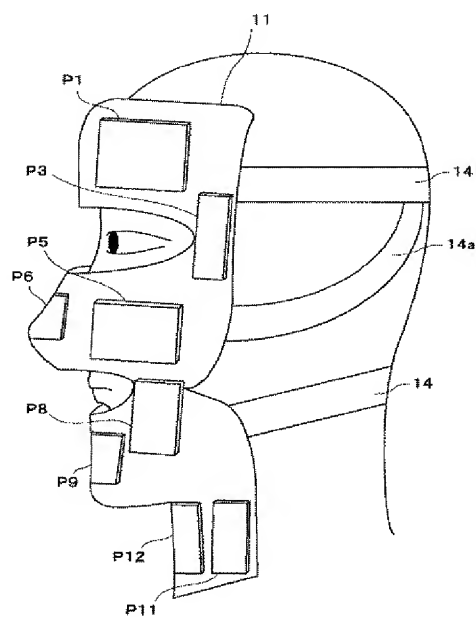
【図1】



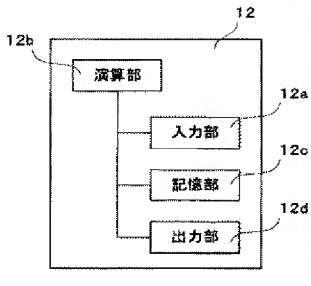
【図2】



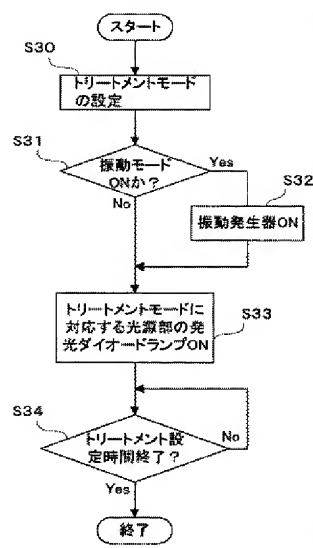
【図3】



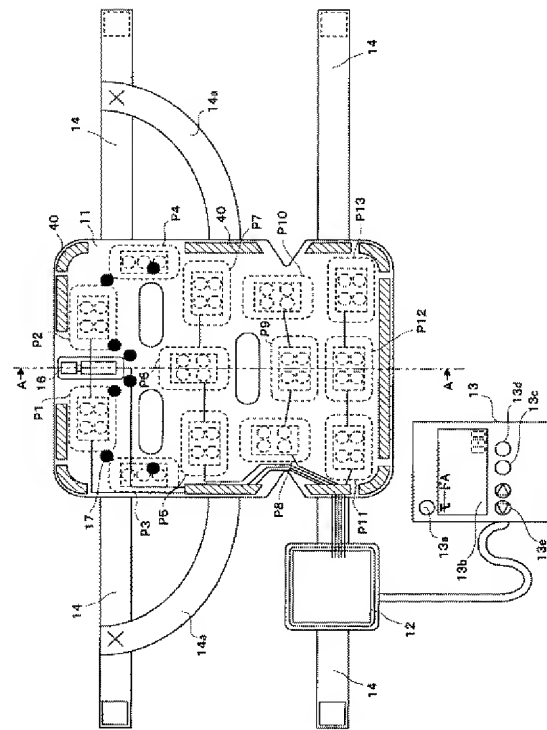
【図4】



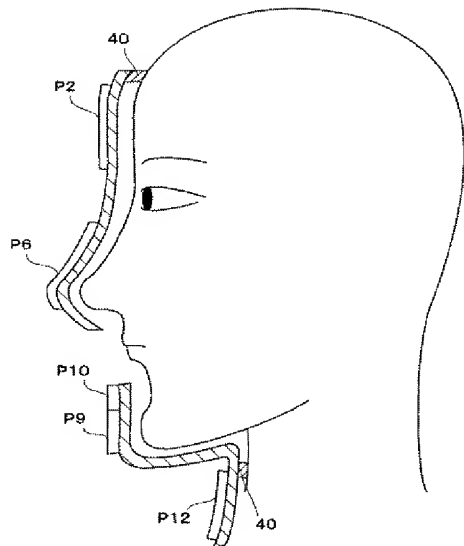
【図5】



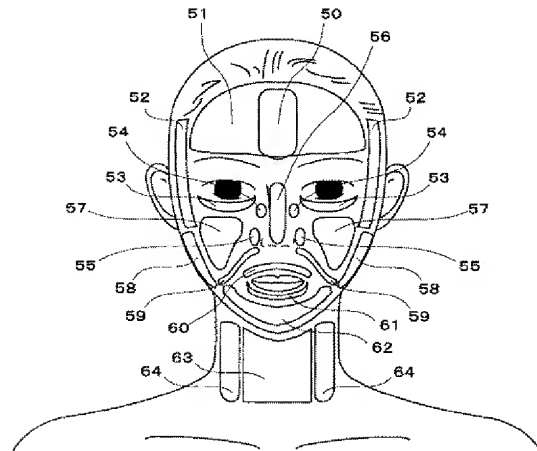
【図6】



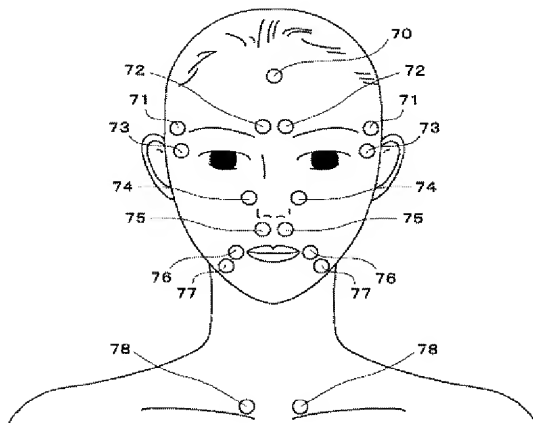
【図7】



【図8】



【図9】

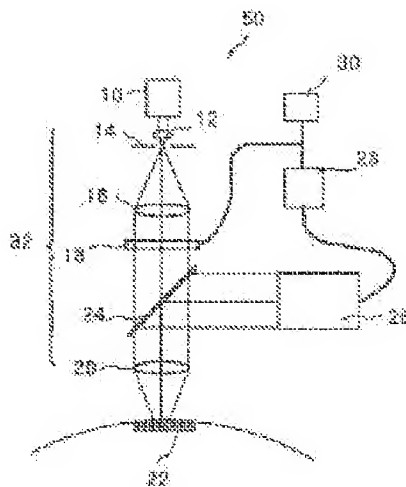




**LASER TREATMENT APPARATUS****Publication number:** JP9084803 (A)**Publication date:** 1997-03-31**Inventor(s):** NAKAMURA TOSHIHISA; HATTORI TOMOHIKO**Applicant(s):** TERUMO CORP**Classification:****- international:** A61B18/20; A61N5/06; A61B18/20; A61N5/06; (IPC1-7): A61B17/36; A61N5/06**- European:****Application number:** JP19950249509 19950927**Priority number(s):** JP19950249509 19950927**Abstract of JP 9084803 (A)**

**PROBLEM TO BE SOLVED:** To obtain a laser treatment apparatus enabling selective irradiation by arbitrarily changing the shape of the mask set to an irradiation optical system on the basis of the modified image of the image of the lesion part on the imaged surface of the body or body cavity.

**SOLUTION:** The laser beam emitted from a laser oscillator 10 is expanded by a beam expander to be collimated by a collimate lens 16 to reach the surface of a lesion part 22 by an irradiation optical system 32. The laser beam transmitted through the shape changeable mask 18 arranged to the irradiation optical system 31 is condensed to the surface of the lesion part 22 by a condensing lens 20 to perform laser treatment matched with the shape of the mask 18. At this time, the reflected beam from the surface of the lesion part 22 is taken out of the irradiation optical system 32 by a half mirror 24 to be guided to a television camera 26. Herein, the shape of the shape changeable mask 18 is altered and the adjustment of a light cut-off region is performed to control the laser treatment shape on the surface of the lesion part 22.



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(19)日本国特許庁 (J P)

(12) 公 開 特 許 公 報 (A)

(11)特許出願公開番号

特開平9-84803

(43)公開日 平成9年(1997)3月31日

(51)Int.Cl. <sup>6</sup>	識別記号	庁内整理番号	F I	技術表示箇所
A 6 1 B 17/36	3 5 0		A 6 1 B 17/36	3 5 0
A 6 1 N 5/06			A 6 1 N 5/06	E

審査請求 未請求 請求項の数3 O L (全 4 頁)

(21)出願番号 特願平7-249509

(22)出願日 平成7年(1995)9月27日

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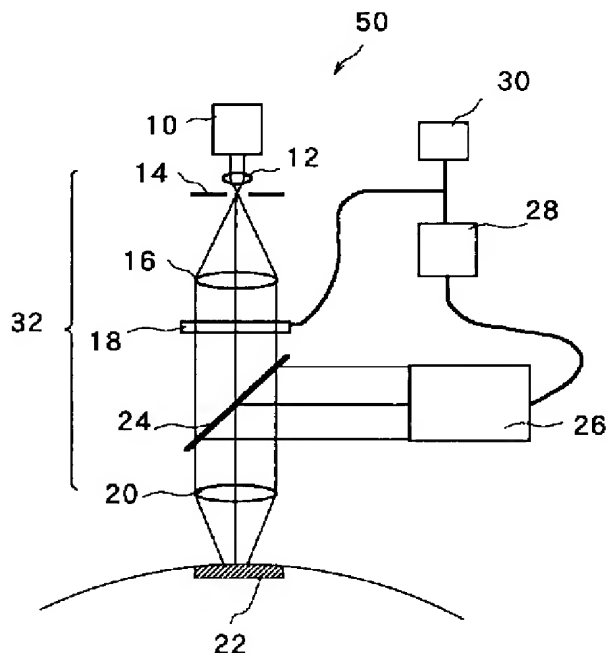
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(54)【発明の名称】 レーザ治療装置

(57)【要約】

【課題】レーザ治療装置内の照射光学系にセットしたマスクの形状を、撮像した病変部の変調像により任意に変化させることの可能なレーザ治療装置を提供する。

【解決手段】レーザ光を照射するレーザ光源10と、レーザ光を病変部22表面に集光する照射光学系32と、病変部22表面で反射されたレーザ光を照射光学系32から取り出す撮像光学系24と、撮像光学系24により取り出されたところの病変部22表面で反射された反射光を撮像するカメラ26と、照射光学系内32に設けられ、レーザ光の病変部22表面への照射形状を変更する形状可変マスク18と、カメラ26により撮像された画像に基づいて、形状可変マスク18によるレーザ光の照射形状変更動作を制御する制御装置28とを具備する。



**【特許請求の範囲】**

【請求項1】 レーザ光を照射するレーザ光源と、前記レーザ光を病変部に集光する照射光学系と、前記病変部の映像を取り出す撮像光学系と、該撮像光学系により取り出されたところの前記病変部表面で反射された反射光を撮像するカメラと、前記照射光学系内に設けられ、前記レーザ光の前記病変部表面への照射形状を変更する形状可変マスクと、前記カメラにより撮像された画像に基づいて、前記形状可変マスクによるレーザ光の照射形状変更動作を制御する制御装置とを具備することを特徴とするレーザ治療装置。

【請求項2】 前記形状可変マスクは、液晶を用いて前記レーザ光の透過形状を変更するマスクであることを特徴とする請求項1に記載のレーザ治療装置。

【請求項3】 前記形状可変マスクは、ファインセラミックスを用いて前記レーザ光の透過形状を変更するマスクであることを特徴とする請求項1に記載のレーザ治療装置。

**【発明の詳細な説明】****【0001】**

【発明の属する技術分野】本発明は体表面もしくは体腔内病変部にマスクを介したレーザ光を照射しレーザ治療を行うレーザ治療装置に関する。

**【0002】**

【従来の技術】従来より、レーザの持つ単色性、指向性、収束性、高輝度性等の優れた光学特性を利用して生体組織の治療への適用が盛んになされ、病変部の切除、血液凝固、組織凝固等の治療が行われている。これらのレーザ治療においては、照射するレーザの波長とエネルギー密度、そして被照射物である生体組織の光学特性および、治療行為の種類によって適当な装置が選択され用いられてきた。しかしながら、いずれの装置を用いた場合にもレーザ照射部位の制御は難しく、病変部のみに照射を行い周辺の正常組織に影響を及ぼさないようにするには、レーザ光を絞り、病変部周囲の正常組織にはレーザを当てないようにすることが必要であった。そのため術者は、かなりの注意と労力を払わねばならなかった。また組織の凝固のように、レーザのビーム径を極端には絞らずに生体組織の比較的広い面積に照射する場合などは、部分的に存在する正常組織にまでレーザ照射してしまうことがあった。これを避けるためには、複数の箇所に分割して正常組織を残すようにレーザ照射をする必要があった。

**【0003】**

【発明が解決しようとする課題】従って、本発明は上述した課題に鑑みてなされたものであり、レーザ治療装置の照射光学系にセットしたマスクの形状を、撮像した体表面もしくは体腔の病変部映像の変調像により任意に変化させることで選択照射の可能なレーザ治療装置を供給

することを目的とする。

**【0004】**

【課題を解決するための手段】上述した課題を解決し目的を達成するために、本発明に係わるレーザ治療装置は、レーザ光を照射するレーザ光源と、前記レーザ光を病変部に集光する照射光学系と、前記病変部の映像を取り出す撮像光学系と、該撮像光学系により取り出されたところの前記病変部表面で反射された反射光を撮像するカメラと、前記照射光学系内に設けられ、前記レーザ光の前記病変部表面への照射形状を変更する形状可変マスクと、前記カメラにより撮像された画像に基づいて、前記形状可変マスクによるレーザ光の照射形状変更動作を制御する制御装置とを具備することを特徴としている。

【0005】また、この発明に係わるレーザ治療装置において、前記形状可変マスクは、液晶を用いて前記レーザ光の透過形状を変更するマスクであることを特徴としている。

【0006】また、この発明に係わるレーザ治療装置において、前記形状可変マスクは、ファインセラミックスを用いて前記レーザ光の透過形状を変更するマスクであることを特徴としている。

**【0007】**

【発明の実施の形態】以下、本発明の好適な一実施形態について、添付図面を参照して詳細に説明する。

【0008】図1は、一実施形態のレーザ治療装置の基本構成を示す図である。

【0009】図1において、レーザ治療装置50は、レーザ光を発振するレーザ発振器10と、レーザ発振器10から照射されたレーザ光を拡大するための凸レンズからなるビームエキスパンダ12と、ビームエキスパンダ12から出射した光の散乱光を除去するための空間フィルタ14と、ビームエキスパンダ12で拡大されたレーザ光を平行光に戻すためのコリメートレンズ16と、コリメートされたレーザ光の形状を病変部22の治療に必要な所望の形状に成形するための形状可変マスク18と、形状可変マスク18を通過したレーザ光を集光するための集光レンズ20とを備えている。また、形状可変マスク18と集光レンズ20との間には、病変部22の表面で反射されたレーザ光をテレビカメラ26に導くためのハーフミラー24が設けられている。テレビカメラ26には制御装置28が接続されており、テレビカメラ26で撮像した映像に基づいて、形状可変マスク18を制御する。また、制御装置28にはテレビモニタ30が接続されており、テレビカメラ26で撮像された映像を術者が観察できるようになされている。

【0010】このように構成されるレーザ治療装置は、以下のように動作する。

【0011】即ち、レーザ発振器10より照射されたレーザ光はビームエキスパンダ12にて拡大され、コリメートレンズ16によりコリメートされた後、照射光学系

32により病変部22の表面に達する。照射光学系32に設置された形状可変マスク18を透過したレーザ光を集光レンズ20にて病変部22の表面に集光させることでマスク18の形状に合わせたレーザ治療を行う。この時ハーフミラー24によって、病変部22の表面からの反射光を照射光学系32から取り出し、病変部22の表面の状態を観察できるように、テレビカメラ26に導く。テレビカメラ26により取り込んだ病変部22の表面の映像は制御装置28による演算処理後、変調像とし形状可変マスク18に入力される。これにより形状可変マスク18のマスク形状の変更を行い、遮光部位の調整を行って病変部22の表面でのレーザ治療形状の制御を行う。すなわち、テレビカメラ26で撮像された所の、病変部22の表面形状及びその表面におけるレーザ光の照射形状が病変部22上を治療しようとする形状に適さない場合は、形状可変マスク18の光透過状態を変更し、レーザ光の照射形状及び照射強度を治療に適したものとなるよう制御する。このとき、テレビモニタ30に接続することで、病変部22の表面の映像および形状可変マスク18に入力する変調像を観察する。マスク18への病変部22の変調像の入力は連続的もしくは段階的に行うことで、レーザ照射にともない病変部形状が変化する場合にも効果的な治療を行うことが出来る。なお各構成部材の位置、大きさおよび形状は本発明の趣旨に反しない限り任意である。また、本発明に基づくレーザ治療装置において発振、及び治療に用いるレーザの波長は任意であり、レーザ照射光学系と撮像光学系において必ずしも同一波長である必要はない。また、撮像系での病変部観察は可視光に限定されるものではなく病変部組織によって発する励起光等を位置検出の手段としても良い。

【0012】また、図2に示すような反射鏡80と中空管81、関節部82及び集光レンズ83を組み合わせたアーム状放射部や、図3に示すような光ファイバ、中空導波路、薄膜導波路などの導光部材84及び集光レンズ85で構成される可撓性チューブ状放射部を用いることにより体腔内病変部の治療も可能となる。次に、図4、図5に変調像を入力することでレーザ遮光部位の形状を変化させることの可能な、形状可変マスク18の構成例を示す。

【0013】図4に示すように、一対の透明電極40及び偏光方位角の直交する一対の偏光板42の間に、透過光の偏光特性を変化させることの可能な光透過性の強誘電ファインセラミックスである例えばPLZT[(Pb, La)(Zr, Ti)O<sub>3</sub>]、あるいはTN液晶44を挟むことにより光学素子46を構成する。この光学素子46が形状可変マスク18の1画素を構成する。すなわち、光学素子46を、図5のようにマトリックス状に配置し、個々の光学素子46に加工物22の表面の映像の変調像を入力することで、レーザ透過位置、遮光位置の制

御及び透過の割合の制御を行い形状可変マスク18とする。形状可変マスクの本体及び各構成部品の位置、大きさ、形状は本発明の趣旨に反しない限り任意である。

【0014】また、上記の実施形態のような偏光を利用して透過光の制御を行う光学素子以外にも透過及び散乱特性を利用した光学素子を用いて形状可変マスクを構成しても良い。図6に示すように、屈折率異方性のある液晶等の媒体60を適当に分散させた媒体62を二枚の透明電極64で挟み込み、照射した光の透過、散乱を電場によって制御する光学素子を、マトリックス状に配置する。このマトリックスの後方に集光レンズ66とアパーチャー68及びアパーチャー68を通過した光を再び平行光にするためのレンズ70を配置する。そして、上記の光学素子各々に加工物22の表面の映像の変調像を入力することで、形状可変マスクとする。形状可変マスクの本体及び各構成部品の位置、大きさ、形状は本発明の趣旨に反しない限り任意である。

【0015】

【発明の効果】以上説明したように、本発明によれば、病変部の映像を撮像光学系より取り込み、この映像の変調像を形状可変マスクに入力することにより、マスクを介してのレーザ治療における照射面形状及び照射強度を制御することが出来る。

【0016】

【図面の簡単な説明】

【図1】本発明の一実施形態のレーザ治療装置の構成例を示した図である。

【図2】アーム状レーザ放射部の構成を示す図である。

【図3】可撓性チューブ状レーザ放射部の構成を示す図である。

【図4】偏光を利用して透過光の制御を行う光学素子の構成例を示した図である。

【図5】形状可変フィルタの構成例を示した図である。

【図6】透過及び散乱特性を利用した光学素子の説明図である。

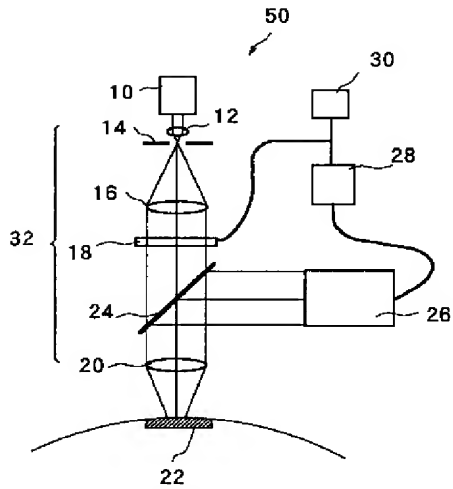
【符号の説明】

- 10 レーザ発振器
- 12 ビームエキスパンダ
- 14 空間フィルタ
- 16 コリメートレンズ
- 18 形状可変フィルタ
- 20 集光レンズ
- 22 病変部
- 24 ハーフミラー
- 26 テレビカメラ
- 28 制御装置
- 30 テレビモニタ
- 32 照射光学系
- 40 透明電極
- 42 偏光板

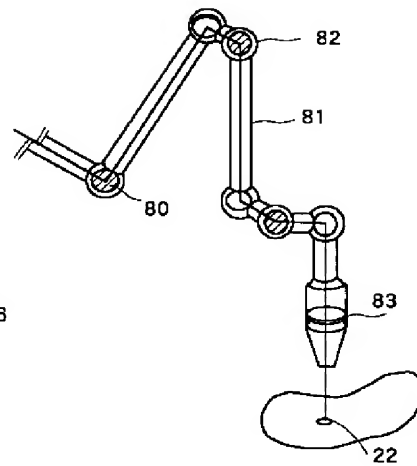
44 透過光の偏光特性を変えることの可能な物質  
 46 光学素子  
 50 レーザ治療装置  
 60, 62 媒体

64 透明電極  
 66 集光レンズ  
 68 アパーチャー

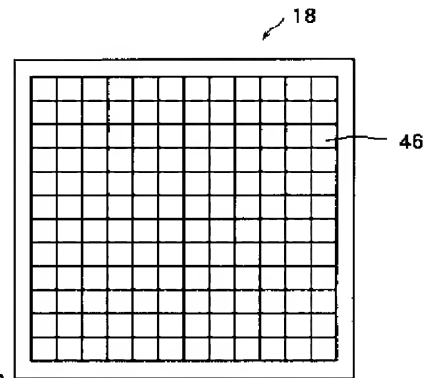
【図1】



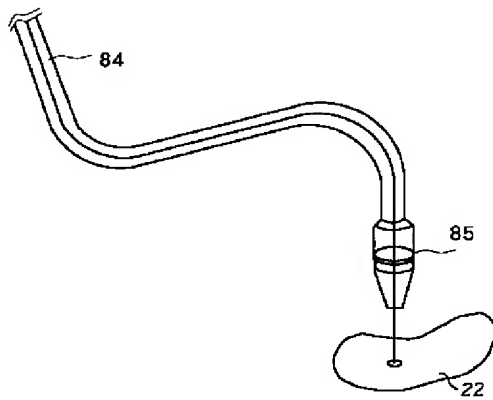
【図2】



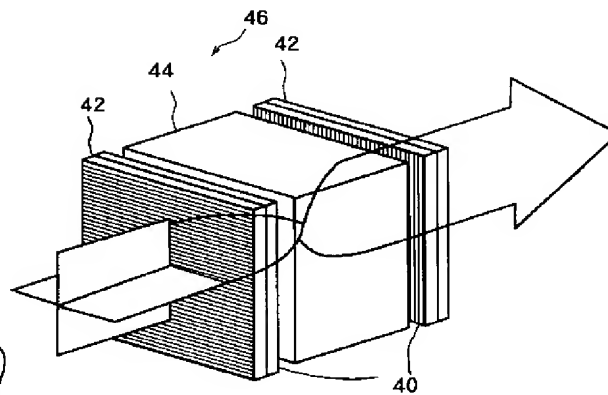
【図5】



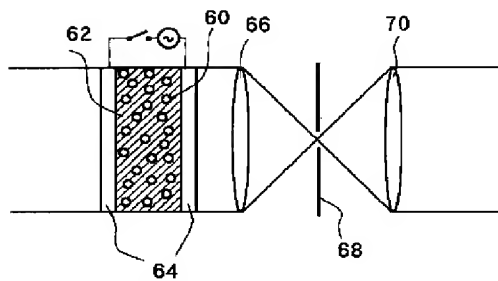
【図3】



【図4】



【図6】





(19) **RU** <sup>(11)</sup> **2 082 337** <sup>(13)</sup> **C1**  
(51) МПК<sup>6</sup> **A 61 B 17/36**

РОССИЙСКОЕ АГЕНТСТВО  
ПО ПАТЕНТАМ И ТОВАРНЫМ ЗНАКАМ

(12) **ОПИСАНИЕ ИЗОБРЕТЕНИЯ К ПАТЕНТУ РОССИЙСКОЙ ФЕДЕРАЦИИ**

(21), (22) Заявка: 95105406/14, 10.04.1995

(46) Дата публикации: 27.06.1997

(56) Ссылки: 1. Заявка Японии N 61-16168, кл. A 61 B 17/36, 1986. 2. Патент ЕПВ N 0073617, кл. A 61 B 17/36, 1983.

(71) Заявитель:  
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(72) Изобретатель: Альтшулер Григорий Борисович

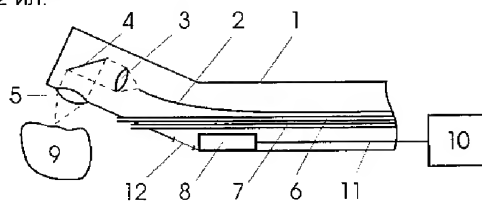
(73) Патентообладатель:  
Альтшулер Григорий Борисович

(54) **НАКОНЕЧНИК ЛАЗЕРНОЙ СИСТЕМЫ ДЛЯ ОБРАБОТКИ БИОЛОГИЧЕСКОЙ ТКАНИ**

(57) Реферат:

Предлагается устройство, которое может быть использовано в хирургии, ортопедии и стоматологии. Устройство обеспечивает минимальную инвазивность и удобство при проведении лазерных операций. Эти преимущества достигаются благодаря закреплению внутри наконечника лазерной системы обработки биоткани акустического приемника, который является приемником информации о состоянии биологической ткани, необходимой для достижения

оптимального режима обработки. 1 з.п. ф-лы, 2 ил.



ФИГ. 1

RU 2 082 337 C1

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(19) **RU** <sup>(11)</sup> **2 082 337** <sup>(13)</sup> **C1**  
(51) Int. Cl. <sup>6</sup> **A 61 B 17/36**

RUSSIAN AGENCY  
FOR PATENTS AND TRADEMARKS

(12) **ABSTRACT OF INVENTION**

(21), (22) Application: 95105406/14, 10.04.1995

(46) Date of publication: 27.06.1997

(71) Applicant:

Al'tshuler Grigorij Borisovich

(72) Inventor: Al'tshuler Grigorij Borisovich

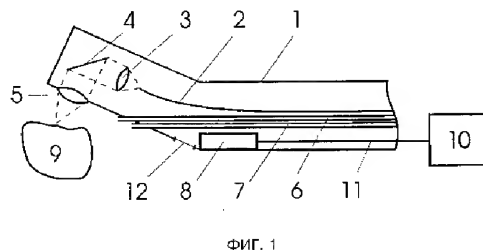
(73) Proprietor:

Al'tshuler Grigorij Borisovich

(54) TIP PIECE OF LASER SYSTEM FOR TREATING BIOLOGICAL TISSUE

(57) Abstract:

FIELD: surgery; orthopedics; stomatology.  
SUBSTANCE: invention offers advantages due to fact that interior of tip piece of laser system for treating biological tissue contains acoustic detector which receives information of state of biological tissue to be treated. Information thus-received serves to optimize tissue treatment process conditions. EFFECT: minimum invasive action.  
2 cl, 2 dwg



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Изобретение относится к медицинской технике и может быть использовано в хирургии, ортопедии и стоматологии для обработки мягких и твердых тканей.

Известен наконечник лазерного скальпеля, содержащий средство доставки лазерного излучения до поверхности обрабатываемой биоткани [1]

Основным недостатком данного устройства является отсутствие в нем ирригационного канала, а также средства, позволяющего определять вид обрабатываемой ткани.

Известен также лазерный наконечник для бормашины, который является наиболее близким по технической сущности и принят за прототип [2]

Этот наконечник содержит, кроме средства доставки лазерного излучения, средство доставки до поверхности обрабатываемой биоткани орошающей жидкости.

Основным недостатком прототипа является отсутствие в нем приемника информации о состоянии обрабатываемой ткани, позволяющего определить ее вид.

Задача, на решение которой направлено изобретение, заключается в создании устройства, обеспечивающего удобство проведения лазерной обработки биоткани при одновременном определении вида и состояния обрабатываемой биоткани, что, в свою очередь, обеспечивает минимальную инвазивность.

Задача решается при осуществлении изобретения за счет технического результата, заключающегося в оптимизации условий приема информации о состоянии обрабатываемой ткани.

Технический результат достигается тем, что внутри наконечника лазерной системы для обработки биологической ткани, содержащем средство доставки лазерного излучения до поверхности биоткани, закреплен акустический приемник, вход которого сопряжен с местом воздействия на биоткань, так что соотношение расстояния от оптической оси на выходе наконечника до входной поверхности акустического приемника и расстояния от поверхности наконечника в месте его оптического выхода до места воздействия на биоткань находится в пределах от 1: 5 до 4:1. Электрический выход акустического приемника соединен с блоком регистрации посредством экранированного кабеля.

В наконечнике может содержаться средство доставки орошающей жидкости до поверхности биоткани.

Известно, что эффективность лазерной обработки биологической ткани с одновременным обеспечением низкой инвазивности (степени некроза) зависит от длины волны и мощности лазерного излучения, энергии и времени лазерного воздействия и, для некоторых видов ткани, жидкостного орошения зоны лазерной обработки (см. например, *Proceeding of Laser-Tissue Interaction V* 24-27, January 1994, Los Angeles, California, Vol 2134A).

Исследования, проведенные автором, показали, что при этом необходима одновременная оптимизация указанных параметров для каждого вида биоткани.

Иными словами, необходимы:

возможность выбора оптимальных длин

волн излучений лазеров или их смеси,

регистрация процесса лазерной деструкции, вида и состояния биоткани и управления длиной волны, мощностью, энергией и временем лазерного воздействия, система орошения зоны лазерной обработки.

Оптимизация режима обработки возможна при наличии системы обратной связи, обеспечивающей управление параметрами лазерного излучения в зависимости от состояния и вида обрабатываемой ткани, т.е. необходим приемник информации о состоянии обрабатываемой ткани, выход которого соединен с блоком управления параметрами лазерного излучения.

Приемником информации о состоянии обрабатываемой ткани может быть акустический приемник звуковой волны, которая образуется в результате лазерного разрушения биоткани. Для различных тканей амплитуда акустической волны различна (см. Renso Salimbeni "Shock wave models keep laser surgeons on target" *Opt Laser Europe* June 1994, p.p. 37-39).

При разрушении биоткани между началом воздействия лазерного импульса и появлением акустического сигнала наблюдается временная задержка. Величина этой задержки определяется тремя факторами: расстоянием от источника звука, которым является облучаемая поверхность биоткани, до приемника, регистрирующего акустический импульс; интенсивностью лазерного излучения на поверхности обрабатываемой ткани и величиной порога ее разрушения.

Исследования показали, что акустический импульс, возникающий при разрушении биоткани с более низким порогом лазерного разрушения, например дентина, имеет меньшую временную задержку относительно начала лазерного импульса, чем акустический импульс, возникающий при разрушении ткани с более высоким порогом разрушения, например эмали (см. G.B. Altshuler, A.V. Belikov, at all "Acoustic response of hard dental tissues to pulsed laser action". *SPIE VOL 2080. Dental Applications of Lasers*, 1993, p.p. 97-103).

Таким образом, идентификация вида обрабатываемой ткани зависит от точности измерения временной задержки.

Закрепление акустического приемника внутри наконечника освобождает операционное поле от дополнительных приспособлений, сводит к минимуму флуктуацию параметров принятого акустического сигнала и зависимость величины временной задержки от манипуляций оператора, а также защищает акустический приемник от случайных повреждений.

Помещение акустического приемника с электрическим выходом внутрь наконечника влечет за собой наличие в последнем проводника с током. В этом случае необходимо обезопасить как пациента, так и оператора от случайно возможных электрошоковых воздействий. Кроме того, необходима помехоустойчивая передача выходных сигналов к блоку их регистрации. Поэтому соединение выхода акустического приемника с блоком регистрации выполнено посредством экранированного кабеля.

По сведениям автора совокупность изложенных в формуле изобретения признаков является новой, а само техническое решение удовлетворяет критерию "изобретательский уровень".

На фиг. 1 схематически изображен бесконтактный наконечник лазерной системы для обработки биоткани; на фиг. 2 контактный наконечник.

Бесконтактный наконечник (фиг. 1) состоит из корпуса 1, внутри которого расположены оптическая система, состоящая из оптического волокна 2, коллимирующей линзы 3, поворотного зеркала 4 и фокусирующей линзы 5, а также водопроводящая трубка 6 и воздухопроводящая трубка 7. Акустический приемник 8 закреплен внутри наконечника таким образом, что его акустический вход обращен к месту воздействия на биоткань 9 (источнику акустической волны), а электрический выход соединен с блоком регистрации 10 посредством экранированного кабеля 11. Перед входом акустического приемника 8 на поверхности наконечника расположена диафрагма 12. Рабочий инструмент 13 (волокно или сапфировый стержень) контактного наконечника показан на фиг. 2. При работе с ним место воздействия на биоткань 9 удалено от поверхности наконечника больше, чем при работе с бесконтактным наконечником.

Месторасположение акустического приемника 8 определено из следующих соображений.

Учитывая, что наименьшее расстояние от поверхности наконечника до места воздействия на биоткань 9 может меняться и для различных видов тканей и обработки колеблется от 8,5 до 20 мм, а диаметр фокусирующей линзы 5 равен 3 мм от оптической оси фокусирующей линзы 5 по направлению, перпендикулярному этой оси. Максимально возможное удаление акустического приемника 8 от места воздействия на биоткань 9 ограничивается снижением чувствительности блока регистрационного акустического сигнала и экранированием входа акустического приемника 8 рукой оператора и составляет 34 мм. Учитывая форму наконечника, акустический приемник 8 закреплен перед ближайшей к месту воздействия на ткань вершиной угла изгиба тела наконечника так, что соотношение расстояния от оптической

оси до входной поверхности акустического приемника 8 и расстояния от поверхности наконечника в месте его оптического выхода до места воздействия на биоткань, находятся в пределах от 1:5 до 4:1.

Исследования, проведенные автором, показали, что при расположении акустического приемника в указанных пределах акустическая волна, образующаяся при лазерной абляции биотканей, имеет амплитуду, достаточную для регистрации акустическими приемниками, кроме того, в этих пределах амплитуда акустической волны несет информацию о типе обрабатываемой ткани.

Диафрагма 12 может быть выполнена из металлической формы или полимерной пленки, роль которых заключается в защите входной поверхности акустического приемника 8 от разлетающихся частичек биоткани 9 и брызг воды, а также является резонатором акустических колебаний.

При практической реализации наконечника в качестве акустического приемника 8 выбран микрофон фирмы Брюль и Кьер 4138 в комплексе с предусилителем 2633 и переходником UA 0160.

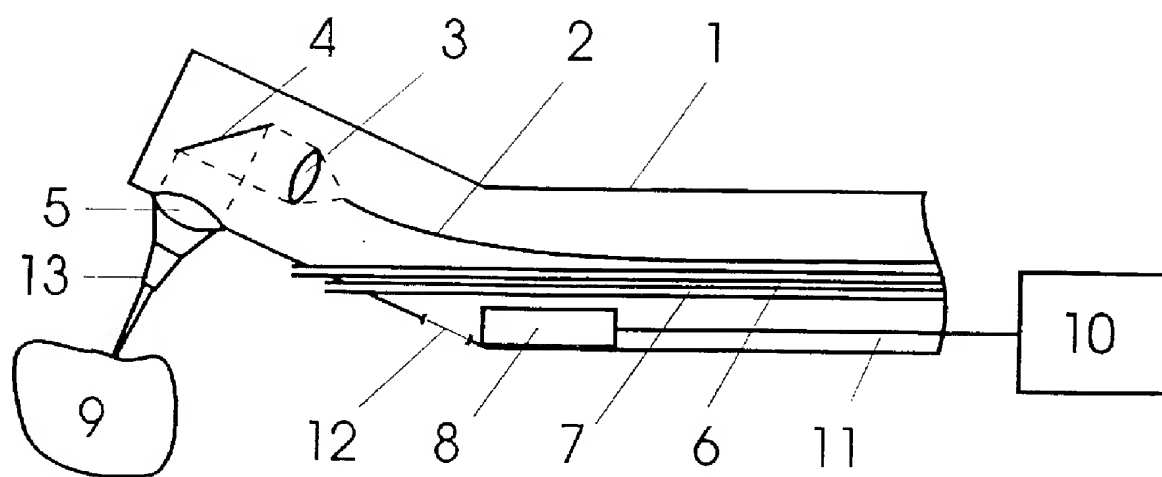
Таким образом, предлагаемое устройство наконечника за счет совокупности заявляемых признаков обеспечивает минимальную травматичность при проведении лазерной обработки биологической ткани в сочетании с удобством проведения обработки.

#### Формула изобретения:





1. Наконечник лазерной системы для обработки биологической ткани, содержащий средство доставки лазерного излучения до поверхности биоткани, отличающийся тем, что внутри него закреплен акустический приемник, вход которого сопряжен с местом воздействия на биоткань так, что соотношение расстояния от оптической оси на выходе наконечника до входной поверхности акустического приемника и расстояния от поверхности наконечника в месте его оптического выхода до места воздействия на биоткань находится в пределах 1 5 4 1, а электрический выход соединен с блоком регистрации посредством экранированного кабеля.

2. Наконечник по п. 1, отличающийся тем, что содержит средство доставки орошающей жидкости до поверхности биоткани.





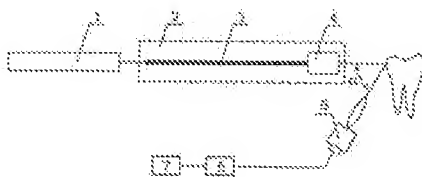
ФИГ. 2

**METHOD OF TREATMENT OF TOOTH HARD TISSUES BY LASER RADIATION AND DEVICE FOR ITS REALIZATION****Publication number:** RU2089126 (C1)**Publication date:** 1997-09-10**Inventor(s):** ALTSHULER GRIGORIY B [RU]; BELIKOV ANDREJ V [RU]; EROFEEV ANDREJ V [RU]**Applicant(s):** UCHEBNO N PROIZV LAZERNYJ TSI [RU]**Classification:****- international:** **A61C5/00; A61B5/00; A61B18/20; A61C1/00; A61B17/00; A61B18/26; A61C5/00; A61B5/00; A61B18/20; A61C1/00; A61B17/00; (IPC1-7): A61C5/00; A61N5/06****- European:** A61C1/00L**Application number:** RU19940012665 19940411**Priority number(s):** RU19940012665 19940411**Also published as:** WO9527446 (A1) EP0755230 (A1) EP0755230 (B1) AT162062 (T)

Abstract not available for RU 2089126 (C1)

Abstract of corresponding document: **WO 9527446 (A1)**

In a tissue-differentiating and laser-control process and in a device for treating hard dental tissue by laser pulses the acoustic pulse generated during the interaction between the laser pulse and the tissue is recorded and examined with respect to its peak amplitude. The type of tissue treated in each case is determined according to the level of the peak amplitude and the radiation energy is, if necessary, adapted to the tissue type. In this way the risk of the patient suffering laser trauma during treatment is simply eliminated or at least reduced.

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(19) **RU** <sup>(11)</sup> **2 089 126** <sup>(13)</sup> **C1**  
(51) МПК<sup>6</sup> **A 61 C 5/00, A 61 N 5/06**

РОССИЙСКОЕ АГЕНТСТВО  
ПО ПАТЕНТАМ И ТОВАРНЫМ ЗНАКАМ

(12) **ОПИСАНИЕ ИЗОБРЕТЕНИЯ К ПАТЕНТУ РОССИЙСКОЙ ФЕДЕРАЦИИ**

(21), (22) Заявка: 94012665/14, 11.04.1994

(46) Дата публикации: 10.09.1997

(56) Ссылки: 1. Патент США N 4521194, кл. A 61 C 5/00, 1986. 2. Авторское свидетельство СССР N 1593669, кл. A 61 C 5/00, 1990. 3. WO, патент, 89/08432, кл. A 61 C 5/00, 1989. 4. WO, патент, 90/01907, кл. A 61 C 5/00, 1989.

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(54) СПОСОБ ОБРАБОТКИ ТВЕРДЫХ ТКАНЕЙ ЗУБА ЛАЗЕРНЫМ ИЗЛУЧЕНИЕМ И УСТРОЙСТВО ДЛЯ ЕГО ОСУЩЕСТВЛЕНИЯ

(57) Реферат:

Изобретение относится к медицинской технике и может быть использовано в стоматологии при лечении кариеса и протезировании зубов. Основным недостатком известных способов обработки твердых тканей зуба лазерным излучением и устройств, реализующих эти способы, является высокая опасность нанесения лазерной травмы пациенту. Целью изобретения является снижение опасности нанесения пациенту лазерной травмы за счет обеспечения возможности определения типа обрабатываемой ткани. Указанная цель достигается тем, что в способе обработки твердых тканей зуба лазерным излучением, включающем воздействие на ткани зуба лазерного импульса, регистрируют акустический импульс, возникающий при взаимодействии излучения с тканью, по пиковой амплитуде которого определяют тип

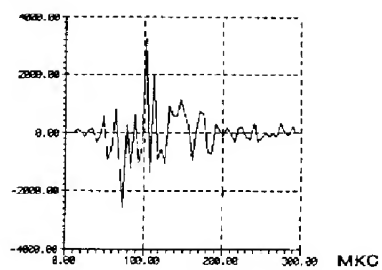
обрабатываемой ткани. Указанная цель также достигается тем, что устройство для обработки твердых тканей зуба лазерным излучением, состоящее из последовательно расположенных вдоль оптической оси импульсного лазера и средства доставки излучения от лазера к зубу, вход которого оптически сопряжен с выходом лазера, содержит акустический приемник и измеритель пиковой амплитуды электрических импульсов, вход которого электрически сопряжен с выходом акустического приемника, а выход электрически сопряжен со входом устройства индикации, причем акустический приемник установлен таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол  $\alpha$ , удовлетворяющий условию:  $11^\circ < \alpha < 86^\circ$ . 2 с. и 4 з.п.ф-лы, 5 ил.

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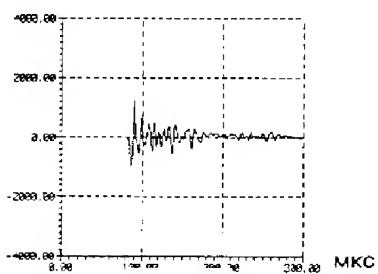
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o.e.



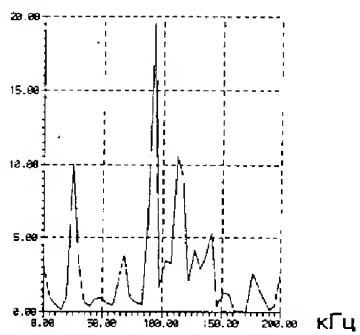
a)

o.e.



б)

o.e.



в)

фиг.1

RU 2089126 C1



(19) **RU** <sup>(11)</sup> **2 089 126** <sup>(13)</sup> **C1**  
(51) Int. Cl.<sup>6</sup> **A 61 C 5/00, A 61 N 5/06**

RUSSIAN AGENCY  
FOR PATENTS AND TRADEMARKS

(12) **ABSTRACT OF INVENTION**

(21), (22) Application: 94012665/14, 11.04.1994

(46) Date of publication: 10.09.1997

(71) Applicant:  
Uchebno-nauchno-proizvodstvennyj "Lazernyj  
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(72) Inventor: Al'tshuler G.B.,  
Belikov A.V., Erofeev A.V.

(73) Proprietor:  
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tsentr" Instituta tochnoj mekhaniki i optiki

(54) METHOD OF TREATMENT OF TOOTH HARD TISSUES BY LASER RADIATION AND DEVICE FOR ITS  
REALIZATION

(57) Abstract:

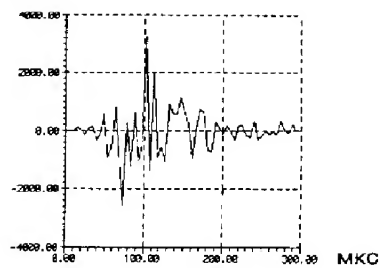
FIELD: medical equipment, applicable in  
stomatology at treatment of caries and  
dental prosthetics. SUBSTANCE: the method  
consists in action of laser pulse on the  
tooth tissue, acoustic pulse arising at  
interaction of radiation with the tissue is  
detected, and the type of the tissue to be  
treated is determined according to the pulse  
peak amplitude. The device uses a pulsed  
laser and means for delivery of radiation  
from the laser to the tooth arranged in  
succession from the laser to the tooth  
arranged in succession in the optimal axis;  
the input of the means of radiation delivery  
is optically integrated with the laser  
output, has an acoustic pickup and an  
electric pulse peak amplitude meter, whose  
input is electrically coupled to the  
acoustic pickup output, and the output is  
electrically coupled to the display unit  
input; the acoustic pickup is installed in  
such a manner that the direction of its  
maximum sensitivity makes up angle  $\alpha$  with  
the direction of the optical axis at the  
output of the radiation delivery means, this  
angle satisfies condition:  $11^\circ < \alpha < 86^\circ$ . EFFECT:  
reduced danger of laser injury to patient. 6  
cl, 5 dwg

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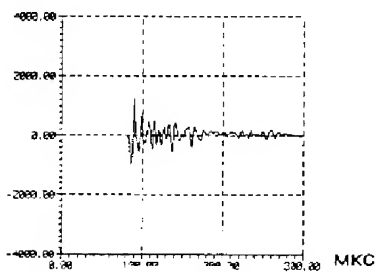
RU 2089126 C1

o.e.



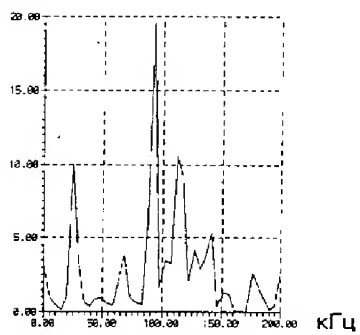
a)

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б)

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в)

фиг.1

RU 2089126 C1

Изобретение относится к медицинской технике и может быть использовано в стоматологии при лечении кариеса и протезировании зубов.

Известен способ удаления начальных кариозных повреждений и/или камней зуба (патент USA 4521194, A 61 C 5/00, приоритет 22.12.83 г.), включающий обработку твердых тканей зуба импульсным лазерным излучением. Основным недостатком данного способа является высокая опасность нанесения лазерной травмы при обработке твердых тканей зуба.

Наиболее близким по технической сущности и принятым за прототип является способ лечения неосложненного кариеса (а. с. СССР N 1593669, A 61 C 5/00, приоритет 14.11.85 г. опубл. 23.09.90 г. БИ N 35), включающий обработку твердых тканей зуба лазерным излучением с длиной волны 2,94 мкм, длительностью импульсов 100-500 мкс, мощностью 0,5-1,0 Дж/имп, плотностью мощности  $2 \cdot 10^4 \pm 3 \cdot 10$  Вт/см<sup>2</sup>, частотой 1 Гц, экспозицией 3-30 с. Основным недостатком прототипа является опасность нанесения лазерной травмы при обработке тканей зуба, связанная с отсутствием в прототипе процедуры определения типа обрабатываемой ткани.

Известно устройство для обработки твердых тканей зуба лазерным излучением (патент WO 89/08432, A 61 C 5/00, приоритет 10.03.89 г.), включающее последовательно расположенные вдоль оптической оси импульсный лазер и средство доставки излучения к зубу в виде оптического волокна. Основным недостатком данного устройства является высокая опасность нанесения лазерной травмы при обработке твердых тканей зуба.

Наиболее близким по технической сущности и принятым за прототип является устройство для обработки твердых тканей зуба лазерным излучением (патент WO 90/01907, A 61 C 5/00, приоритет 25.08.89 г.), содержащее последовательно расположенные вдоль оптической оси импульсный лазер и средство доставки излучения к зубу, включающее отрезок оптического волокна, вход которого оптически сопряжен с выходом лазера, и наконечник, вход которого оптически сопряжен с выходом оптического волокна, а выход является выходом устройства. Основным недостатком прототипа является опасность нанесения лазерной травмы при обработке тканей зуба, связанная с отсутствием в прототипе системы определения типа обрабатываемой ткани.

Задачей, на решение которой направлено заявляемое изобретение, является снижение опасности нанесения пациенту лазерной травмы за счет обеспечения возможности определения типа обрабатываемой ткани.

Указанная задача достигается тем, что в способе обработки твердых тканей зуба лазерным излучением, включающем воздействие на ткани зуба лазерного импульса, регистрируют акустический импульс, возникающий при взаимодействии излучения с тканью, по пиковой амплитуде которого определяют тип обрабатываемой ткани. Для повышения достоверности определения типа обрабатываемой ткани указанный акустический импульс регистрируют в диапазоне звуковых частот

85-95 кГц. С той же целью одновременно с регистрацией акустического импульса измеряют временную задержку между лазерным и акустическим импульсами, по величине которой уточняют тип обрабатываемой ткани.

Указанная задача также достигается тем, что устройство для обработки твердых тканей зуба лазерным излучением, состоящее из последовательно расположенных вдоль оптической оси импульсного лазера и средства доставки излучения от лазера к зубу, вход которого оптически сопряжен с выходом лазера, содержит акустический приемник и измеритель пиковой амплитуды электрических импульсов, вход которого электрически сопряжен со входом устройства индикации, причем акустический приемник установлен таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол  $\alpha$ , удовлетворяющий условию:  $11^\circ < \alpha < 86^\circ$ . Для повышения достоверности определения типа обрабатываемой ткани вход измерителя пиковой амплитуды электрических импульсов электрически сопряжен с выходом акустического приемника через блок спектрального преобразования и фильтрации с полосой пропускания 85-95 кГц. С той же целью устройство дополнительно содержит фоторегистратор и блок измерения временных интервалов, причем вход фоторегистратора оптически сопряжен с выходом лазера, а выход электрически сопряжен с одним из входов блока измерения временных интервалов, второй вход которого электрически сопряжен с выходом акустического приемника, а выход электрически сопряжен со входом устройства индикации.

На фиг. 1 даны: (а) акустический импульс, возникающий при лазерном разрушении дентина, (б) акустический импульс, возникающий при лазерном разрушении эмали, (в) спектральная зависимость отношения акустических импульсов, возникающих при лазерном разрушении дентина и эмали. На фиг. 2 схематически показаны временные диаграммы: (а) интенсивности лазерного импульса, (б) плотности энергии лазерного излучения, падающего на обрабатываемую поверхность, а также акустических импульсов, возникающих при разрушении дентина (в) и эмали (г). На фиг. 3 показана схема устройства по п. 4 формулы изобретения для реализации способа по п. 1 формулы. На фиг. 4 показана схема устройства по п. 5 формулы изобретения для реализации способа по п. 2 формулы. На фиг. 5 показана схема устройства по п. 6 формулы изобретения для реализации способа по п. 3 формулы.

Как известно, к твердым тканям зуба относятся эмаль и дентин. Пороги разрушения этих тканей лазерным излучением различаются в несколько раз, причем порог разрушения дентина ниже, чем порог разрушения эмали. При обработке твердых тканей зуба лазерным излучением на обрабатываемой поверхности возникает эрозийный факел, что делает невозможным визуальный контроль состояния облучаемой

поверхности ткани и определение ее типа. Другими словами, врач не в состоянии определить воздействие излучение на эмаль или дентин непосредственно в процессе обработки. При этом процедура лазерной обработки твердых тканей зуба сопряжена с опасностью нанесения лазерной травмы дентина или пульпы в том случае, если импульсное излучение с энергией, превышающей порог разрушения эмали, попадает на дентин. Основным фактором риска является контузия тканей импульсом отдачи, возникающим при значительном превышении энергии излучения, падающего на обрабатываемую ткань, над значением порога разрушения. Проведенные авторами экспериментальные исследования режимов обработки твердых тканей зуба (G.B.Altshuler, A.V.Belikov, A.V.Erofeev "The damage of hard tooth tissues with laser pulses of different duration", Proceeding 4th International Conference on Laser Application in Life Science, 1992, p. 114) позволили выявить приемлемый с точки зрения безопасности процедуры лазерной обработки зуба диапазон значений плотности энергии излучения. Для эмали допустимым является десятикратное превышение плотности энергии лазерного излучения над порогом разрушения. Для дентина безопасный диапазон примерно вдвое уже (т.е. допустимо лишь пятикратное превышение плотности энергии над порогом), что объясняется непосредственной близостью дентина к пульпе.

Для уменьшения опасности нанесения травмы пациенту при обработке твердых тканей зуба лазерным излучением авторы предлагают идентифицировать тип обрабатываемой ткани (эмаль, дентин) по характеристикам акустических импульсов. Авторами экспериментально показано, что пиковая (максимальная) амплитуда акустического импульса, возникающего при разрушении дентина (фиг. 1а), существенно (в несколько раз) отличается от пиковой амплитуды акустического импульса, возникающего при разрушении эмали (фиг. 1б). Таким образом, введение в способ обработки тканей зуба операции регистрации акустического импульса, возникающего при взаимодействии излучения с тканью, по пиковой амплитуде которого можно определить тип обрабатываемой ткани, дает возможность снижать в случае необходимости энергию излучения, не допуская нанесения лазерной травмы пациенту.

Авторами экспериментально показано также, что наиболее существенное различие пиковых амплитуд акустических импульсов, возникающих при разрушении эмали и дентина, наблюдается в полосе звуковых частот 85-95 кГц. На фиг. 1в изображен график отношения амплитуд спектров акустических импульсов, генерируемых в дентине и эмали. Из рисунка видно, что значение отношения максимально именно в полосе звуковых частот 85-95 кГц, таким образом, спектральная селекция акустических импульсов дает возможность повысить достоверность определения типа обрабатываемой ткани.

При воздействии на ткани зуба импульсного лазерного излучения, энергия которого превышает необходимое для их

разрушения значение, в общем случае наблюдается временная задержка между началом воздействия лазерного импульса и появлением акустического импульса, свидетельствующего о начале разрушения ткани. Величина этой задержки определяется тремя факторами: расстоянием от источника звука, которым является облучаемая поверхность ткани, до акустического приемника, регистрирующего акустический импульс, интенсивностью лазерного излучения на поверхности обрабатываемой ткани и величиной порога ее разрушения (т.е. типом обрабатываемой ткани). На фиг. 2 представлены поясняющие временные диаграммы интенсивности лазерного импульса (а), плотности энергии лазерного излучения, падающего на обрабатываемую поверхность (б), акустических импульсов, возникающих при разрушении дентина (в) и эмали (г). На фиг. 2б пунктиром показаны уровни плотности энергии, соответствующие порогам разрушения эмали и дентина. Из фиг. 2в, г видно, что акустический импульс, возникающий при разрушении дентина, имеет меньшую задержку  $\tau_d$  относительно начала лазерного импульса, чем акустический импульс, возникающий при разрушении эмали ( $\tau_s$ ). Таким образом, измерение временных задержек акустических импульсов предоставляет возможность уточнения типа обрабатываемой ткани.

По сведениям авторов, совокупность изложенных в формуле изобретения признаков является новой, а само техническое решение удовлетворяет критерию "изобретательский уровень".

Заявленный способ по п. 1 формулы изобретения может быть реализован, например, с помощью устройства, схема которого представлена на фиг. 3. На фигуре показаны лазер 1, средство доставки лазерного излучения от лазера к зубу 2, вход которого оптически сопряжен с выходом лазера, включающее оптическое волокно 3 и наконечник 4, акустический приемник 5, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол  $\alpha$  удовлетворяющий условию  $11^\circ < \alpha < 86^\circ$ , измеритель пиковой амплитуды электрических импульсов 6, вход которого электрически сопряжен с выходом акустического приемника, а выход электрически сопряжен со входом устройства индикации 7. Заявляемый способ по п. 2 формулы изобретения может быть реализован, например, с помощью устройства, схема которого представлена на фиг. 4. На фигуре показаны лазер 1, средство доставки лазерного излучения от лазера к зубу 2, вход которого оптически сопряжен с выходом лазера, включающее оптическое волокно 3 и наконечник 4, акустический приемник 5, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол  $\alpha$ , удовлетворяющий условию:  $11^\circ < \alpha < 86^\circ$  измеритель пиковой амплитуды электрических импульсов 6, вход которого



электрически сопряжен с выходом акустического приемника через блок спектрального преобразования и фильтрации 8 с полосой пропускания 85-95 кГц, а выход электрически сопряжен со входом устройства индикации 7. Заявляемый способ по п.3 формулы изобретения может быть реализован, например с помощью устройства, схема которого представлена на фиг.5. На фигуре показаны лазер 1, средство доставки лазерного излучения от лазера к зубу 2, вход которого оптически сопряжен с выходом лазера, включающее оптическое волокно 3 и наконечник 4, акустический приемник 5, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол  $\alpha$  удовлетворяющий условию:  $11^\circ < \alpha < 86^\circ$  измеритель пиковой амплитуды электрических импульсов 6, вход которого электрически сопряжен с выходом акустического приемника, а выход электрически сопряжен со входом устройства индикации 7, а также блок измерения временных интервалов 9 и фоторегистратор 10, причем вход фоторегистратора оптически сопряжен с выходом лазера, а выход электрически сопряжен с одним из входов блока измерения временных интервалов, второй вход которого электрически сопряжен с выходом акустического приемника, а выход электрически сопряжен со входом устройства индикации.

Пример конкретной реализации способа. Перед началом обработки твердых тканей зуба лазерным излучением проводят калибровку измерительного тракта устройства. Для этого устанавливают уровень энергии генерации лазера 1, превышающий значение, соответствующее порогу разрушения эмали. После этого излучение, генерируемое импульсным лазером, через средство доставки 2, включающее оптическое волокно 3 и наконечник 4, направляют на обрабатываемую поверхность калибровочного образца дентина. Одновременно с этим фоторегистратором 10 регистрируют лазерный импульс и в блоке измерения временных интервалов 9 фиксируют момент времени, соответствующий его началу. При разрушении дентина возникает акустический импульс. Этот акустический импульс регистрируют расположенным вблизи облучаемой зоны акустическим приемником 5. Измерителем пиковой амплитуды 6 измеряют пиковую амплитуду акустического импульса и фиксируют момент времени, соответствующий началу акустического импульса. В блоке измерения временных интервалов определяют задержку начала акустического импульса относительно начала лазерного импульса. В блоке спектрального преобразования и фильтрации 8 производят спектральное преобразование (например, Фурье-преобразование) акустического импульса и измеряют пиковую амплитуду спектра акустического импульса в полосе частот от 85 до 95 кГц. Значения пиковой амплитуды, задержки и пиковой спектральной (в указанном диапазоне) амплитуды акустического импульса, возникающего при разрушении дентина, фиксируют в устройстве

индикации 7 в качестве эталонных для дентина. После этого излучение, генерируемое импульсным лазером, через средство доставки направляют на обрабатываемую поверхность калибровочного образца эмали. Одновременно с этим регистрируют лазерный импульс и фиксируют момент времени, соответствующий его началу. При разрушении эмали возникает акустический импульс. Этот акустический импульс регистрируют расположенным вблизи облучаемой зоны акустическим приемником. Измеряют пиковую амплитуду акустического импульса и фиксируют момент времени, соответствующий началу акустического импульса. Определяют задержку начала акустического импульса относительно начала лазерного импульса. Производят спектральное преобразование (например, Фурье-преобразование) акустического импульса и измеряют пиковую амплитуду спектра акустического импульса в полосе частот от 85 до 95 кГц. Значения пиковой амплитуды, задержки и пиковой спектральной (в указанном диапазоне) амплитуды акустического импульса, возникающего при разрушении эмали, фиксируют в качестве эталонных для эмали. После того как получены эталонные значения пиковых амплитуд, задержек и пиковых спектральных амплитуд акустических импульсов, возникающих при разрушении эмали и дентина, импульсное лазерное излучение направляют на обрабатываемую поверхность твердой ткани зуба. Регистрируют акустический импульс, возникающий при разрушении твердой ткани зуба лазерным излучением. Измеряют пиковую амплитуду данного акустического импульса и сравнивают ее с эталонными значениями пиковых амплитуд для эмали и дентина. В том случае, если измеренная пиковая амплитуда акустического импульса  $A$  удовлетворяет условию:  $A < (A_э + A_д)/2$ , где  $A_э$ ,  $A_д$  - эталонные значения пиковой амплитуды акустических импульсов, возникающих при лазерном разрушении эмали и дентина соответственно, то обрабатываемую твердую ткань зуба определяют как эмаль, в противном случае как дентин.

Для повышения достоверности определения типа обрабатываемой ткани производят спектральное преобразование акустического импульса и измеряют пиковое (максимальное) значение амплитуды спектра акустического импульса в полосе частот от 85 до 95 кГц. Сравнивают ее с эталонными значениями пиковых амплитуд спектра для эмали и дентина. В том случае, если измеренная пиковая амплитуда спектра акустического импульса в полосе частот от 85 до 95 кГц  $S$  удовлетворяет условию:  $S < (S_э + S_д)/2$ , где  $S_э$ ,  $S_д$  - эталонные значения пиковой амплитуды спектра акустических импульсов, возникающих при лазерном разрушении эмали и дентина соответственно, то обрабатываемую твердую ткань зуба определяют как эмаль, в противном случае - как дентин.

Для уточнения типа обрабатываемой ткани зуба с помощью фоторегистратора регистрируют лазерный импульс и фиксируют момент его начала, измеряют задержку между началом лазерного импульса и началом

акустического импульса, возникающего при разрушении ткани. Сравнивают ее с эталонными значениями задержек эмали и дентина. В том случае, если измеренная задержка акустического импульса относительно лазерного импульса  $\tau$  удовлетворяет условию:  $t > (\tau_0 + \tau_d) / 2$  где  $\tau_0$ ,  $\tau_d$  эталонные значения задержек акустических импульсов, возникающих при лазерном разрушении эмали и дентина соответственно, то обрабатываемую твердую ткань зуба определяют как эмаль, в противном случае как дентин. Безопасность процедуры обработки твердых тканей зуба лазерным излучением обеспечивается возможностью управления энергией генерации лазера в соответствии с информацией о типе обрабатываемой ткани.

Для получения информации о типе обрабатываемой ткани необходимо регистрировать акустические импульсы, возникающие при разрушении ткани лазерным импульсом. При обработке ткани, однако, возникают акустические импульсы, не связанные непосредственно с разрушением ткани. Их природа состоит в следующем.

Под действием лазерного импульса обрабатываемые твердые ткани зуба разогреваются до высоких температур. Происходит их частичное разрушение и испарение. Разогретые газы под высоким давлением выносят навстречу лазерному излучению частицы ткани. Эти частицы распространяются в воздухе со сверхзвуковой скоростью, в результате чего возникает ударная акустическая волна. Амплитуда ударной волны определяется скоростью и размером частиц, не зависит от типа обрабатываемой ткани и превышает во много раз (примерно в 10 раз) амплитуду полезного акустического импульса, делая его регистрацию практически невозможной. Однако ударная волна имеет особенности по сравнению с акустической волной, возникающей при разрушении ткани. Ударная волна является направленной и распространяется в узком телесном угле в направлении, противоположном направлению распространения лазерного излучения (т.е. по оптической оси). Полезная акустическая волна близка к сферической. Авторами экспериментально установлена полуширина диаграммы направленности ударной акустической волны по уровню 10 максимальной амплитуды. Для широкого круга импульсных лазеров при различных параметрах режимов лазерного воздействия на эмаль и дентин значение полуширины диаграммы направленности ударной волны по данному уровню не превышает 11°. Верхняя граница приемлемого диапазона углов отклонения направления максимальной чувствительности акустического приемника от оптической оси 86° определяется границей акустической тени. Таким образом, предлагаемая в настоящем изобретении конструкция устройства, содержащего акустический приемник, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол  $\alpha$ , удовлетворяющий условию:  $11^\circ < \alpha < 86^\circ$ ,

является необходимым условием достижения решаемой задачи. Диаграмма направленности акустического приемника на фиг.3-5 условно показана штриховкой.

По п. 4 формулы изобретения устройство содержит (см. фиг.3) импульсный лазер 1, выход которого оптически сопряжен со средством доставки излучения от лазера к зубу 2, содержащим последовательно расположенные отрезок оптического волокна 3 и наконечник 4. Акустический приемник 5 установлен таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол, удовлетворяющий заявляемому соотношению, а выход приемника через пиковый детектор 6 электрически сопряжен с устройством индикации 7.

По п.5 формулы изобретения устройство дополнительно содержит (см. фиг.4) блок спектрального преобразования и фильтрации 8 с полосой пропускания 85-95 кГц, установленный таким образом, что его вход электрически сопряжен с выходом акустического приемника 5, а выход электрически сопряжен со входом пикового детектора 6.

По п.6 формулы изобретения устройство дополнительно содержит (см. фиг.5) блок измерения временных интервалов 9 и фоторегистратор 10, причем вход фоторегистратора оптически сопряжен с выходом лазера 1, а выход электрически сопряжен с одним из входов блока измерения временных интервалов, второй вход которого электрически сопряжен с выходом акустического приемника 5, а выход электрически сопряжен со входом устройства индикации 7.

Пример конкретной реализации заявляемого устройства состоит в следующем.

В качестве источника излучения выбран импульсный лазер 1 на ИСГГ:Cr,Er. Средство доставки излучения от лазера к зубу 2 выполнено в виде оптически сопряженных отрезка сапфирового волокна 3 и наконечника 4, содержащего фокусирующую систему с фокусным расстоянием 25 мм, причем оптический вход средства доставки излучения оптически сопряжен с выходом лазера. На расстоянии 45 мм от заднего фокуса расположенной в наконечнике фокусирующей системы расположен микрофон 5 марки B & K4138, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе средства доставки излучения от лазера к зубу угол 28°. Выход микрофона электрически сопряжен через измеритель пиковой амплитуды электрических импульсов (пиковый детектор) 6 с индикатором 7, в качестве которого выбран цифровой вольтметр. Дополнительно устройство содержит блок спектрального преобразования и фильтрации электрических импульсов 8, использующий быстрое преобразование Фурье и реализованный на базе процессора INTEL 386, установленный таким образом, что его вход электрически сопряжен с выходом акустического приемника 5, а выход электрически сопряжен со входом пикового детектора 6. Также устройство

дополнительно содержит фоторегистратор 10 на базе фотодиода ФД34, оптически сопряженный с выходом лазера 1 и электрически сопряженный с одним из входов измерителя временных интервалов 9 на базе цифрового осциллографа С9-16. Второй вход измерителя временных интервалов электрически сопряжен с выходом акустического приемника 5. На выходе измерителя временных интервалов задержка между началом лазерного импульса, регистрируемого фоторегистратором, и началом акустического импульса, регистрируемого акустическим приемником, преобразуется в электрический сигнал, амплитуда которого пропорциональна величине временной задержки. Выход измерителя временных интервалов электрически сопряжен с индикатором 7.

Таким образом, на основании вышеизложенного заявляемая совокупность признаков в способе и устройстве позволяет решить задачу, а именно снизить опасность нанесения травмы пациенту при лазерной обработке твердых тканей зуба при лечении кариеса и протезировании.

#### Формула изобретения:

1. Способ обработки твердых тканей зуба лазерным излучением, включающий воздействие на ткани зуба лазерным импульсом, отличающийся тем, что регистрируют акустический импульс, возникающий при взаимодействии излучения с тканью, по пиковой амплитуде которого определяют тип обрабатываемой ткани.

2. Способ по п.1, отличающийся тем, что акустический импульс регистрируют в диапазоне звуковых частот 85 95 кГц.

3. Способ по п.1, отличающийся тем, что одновременно с регистрацией акустического импульса измеряют временную задержку

между лазерным и акустическим импульсами, по величине которой уточняют тип обрабатываемой ткани.

5 4. Устройство для обработки твердых тканей зуба лазерным излучением, состоящее из последовательно расположенных вдоль оптической оси импульсного лазера и средства доставки излучения от лазера к зубу, вход которого оптически сопряжен с выходом лазера, отличающееся тем, что  
10 устройство содержит акустический приемник и измеритель пиковой амплитуды электрических импульсов, вход которого электрически сопряжен с выходом  
15 акустического приемника, а выход электрически сопряжен с входом устройства индикации, причем акустический приемник установлен так, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе  
20 средства доставки излучения от лазера к зубу угол  $\alpha$ , удовлетворяющий условию  $11^\circ < \alpha < 86^\circ$

5. Устройство по п.4, отличающееся тем, что вход измерителя пиковой амплитуды электрических импульсов электрически  
25 сопряжен с выходом акустического приемника через блок спектрального преобразования и фильтрации с полосой пропускания 85 95 кГц.

6. Устройство по п.4, отличающееся тем, что оно дополнительно содержит  
30 фоторегистратор и блок измерения временных интервалов, причем вход фоторегистратора оптически сопряжен с выходом лазера, а выход электрически сопряжен с одним из входов блока измерения временных интервалов, второй вход которого  
35 электрически сопряжен с выходом акустического приемника, а выход электрически сопряжен с входом устройства индикации.

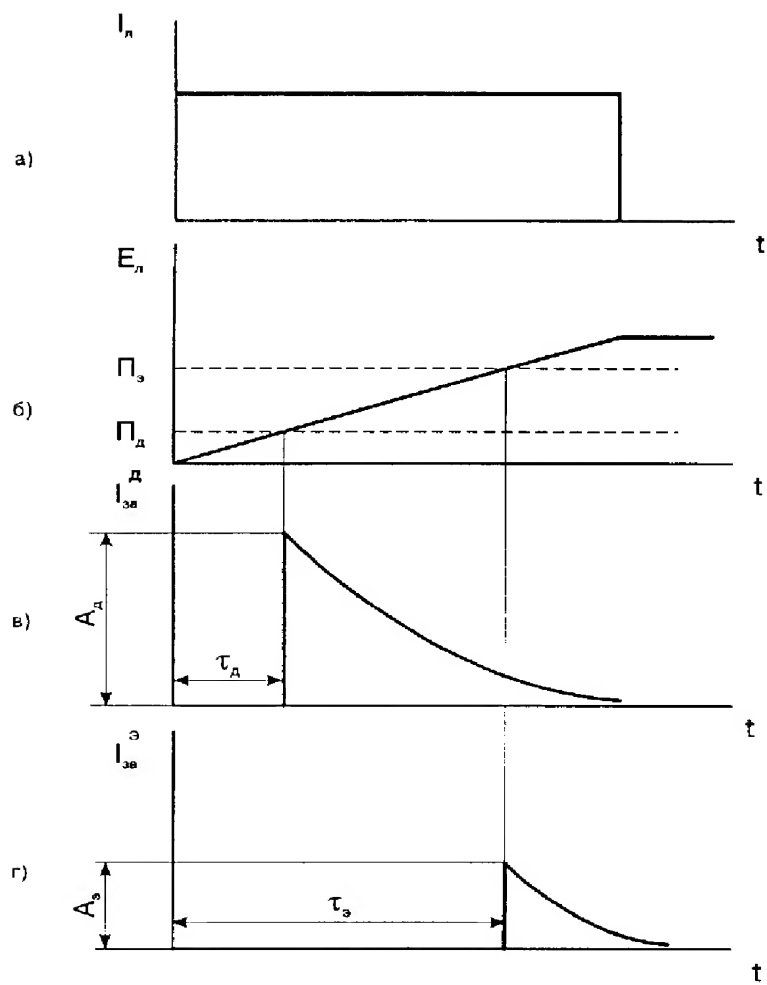
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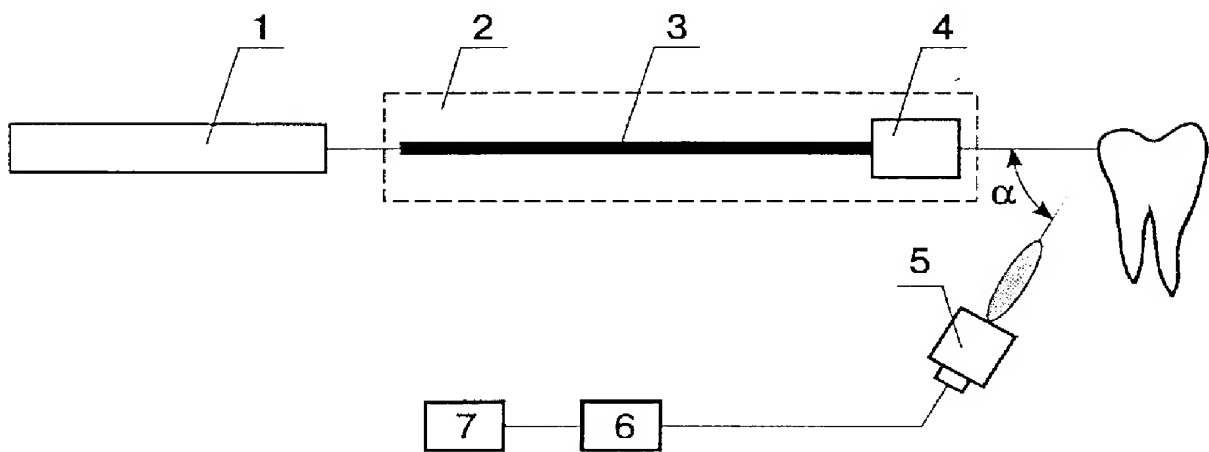
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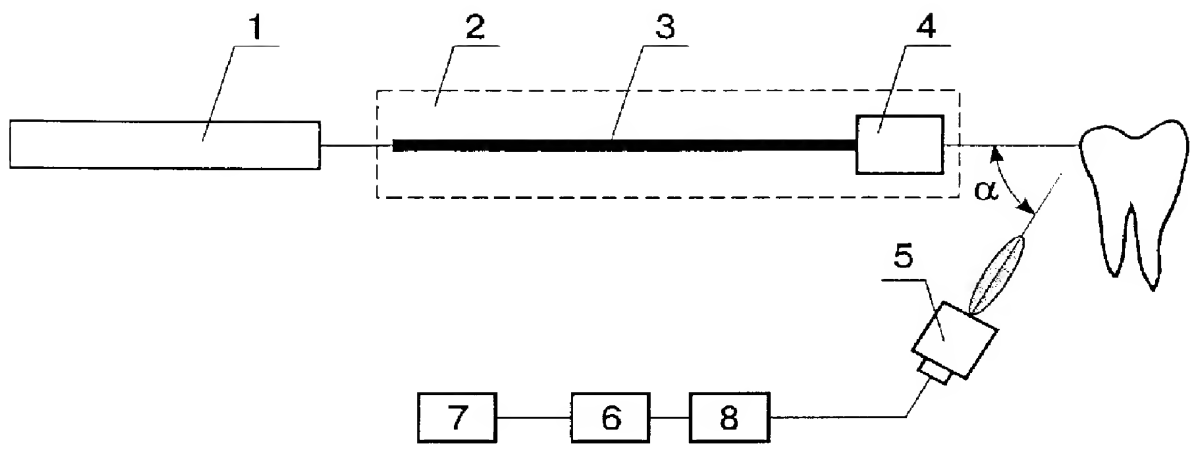
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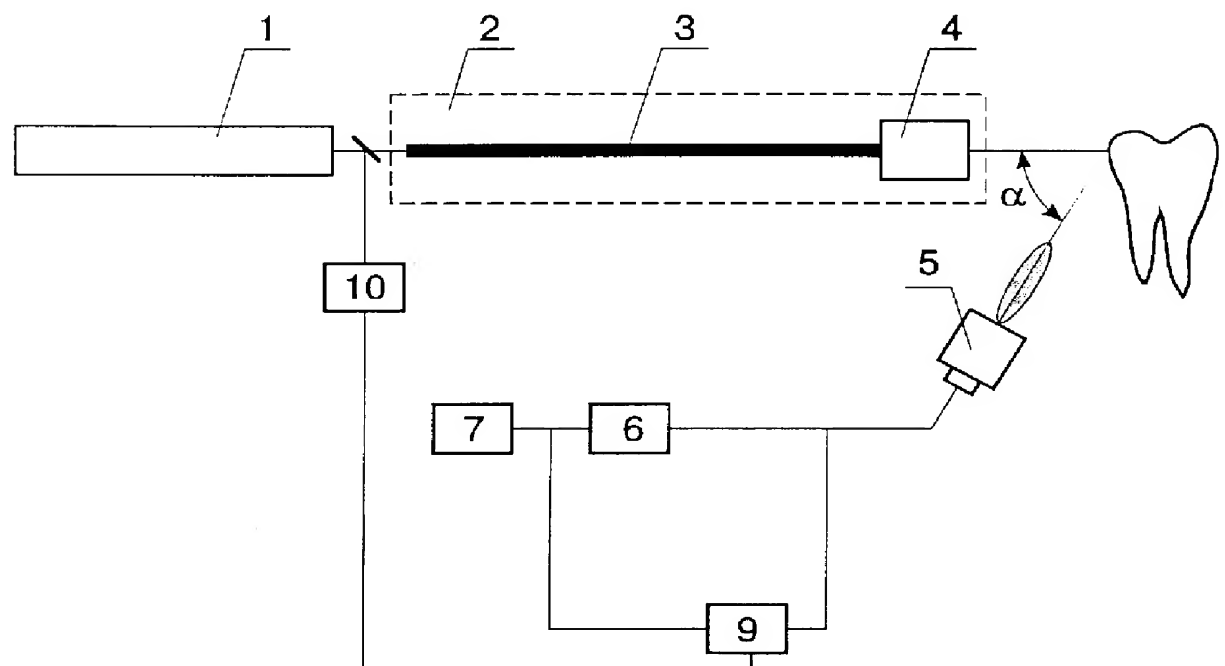
фиг. 2



фиг. 3



фиг. 4



фиг. 5

RU 2089126 C1

RU 2089126 C1



(19) RU<sup>(11)</sup> 2 089 127<sup>(13)</sup> C1  
(51) МПК<sup>6</sup> A 61 C 5/00, A 61 N 5/06

РОССИЙСКОЕ АГЕНТСТВО  
ПО ПАТЕНТАМ И ТОВАРНЫМ ЗНАКАМ

## (12) ОПИСАНИЕ ИЗОБРЕТЕНИЯ К ПАТЕНТУ РОССИЙСКОЙ ФЕДЕРАЦИИ

(21), (22) Заявка: 94040344/14, 02.11.1994

(46) Дата публикации: 10.09.1997

(56) Ссылки: 1. Патент США N 4521194, кл. A 61 G 5/00, 1987. 2. Авторское свидетельство СССР N 1593669, кл. A 61 C 5/00, 1990. 3. WO, патент, 89/08432, кл. A 61 C 5/00, 1989. WO, патент, 90/01907, кл. A 61 C 5/00, 1990.

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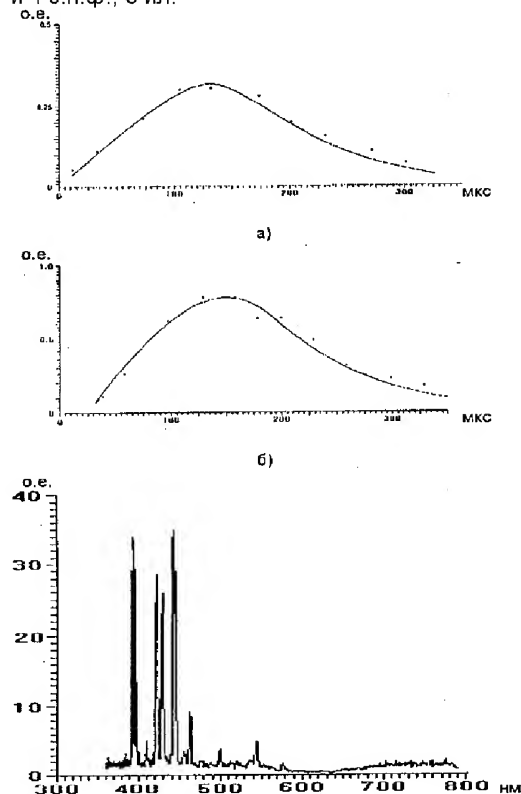
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(54) СПОСОБ ОБРАБОТКИ ТВЕРДЫХ ТКАНЕЙ ЗУБА ЛАЗЕРНЫМ ИЗЛУЧЕНИЕМ И УСТРОЙСТВО ДЛЯ ЕГО ОСУЩЕСТВЛЕНИЯ

(57) Реферат:

Изобретение относится к медицинской технике и может быть использовано в стоматологии при лечении кариеса и протезировании зубов. Основным недостатком известных способов обработки твердых тканей зуба лазерным излучением и устройств, реализующих эти способы, является высокая опасность нанесения лазерной травмы пациенту. Задачей, на решение которой направлено заявляемое изобретение, является снижение опасности нанесения пациенту лазерной травмы за счет обеспечения возможности определения типа обрабатываемой ткани. Указанная задача достигается тем, что в способе обработки твердых тканей зуба лазерным излучением, включающем воздействие на ткани зуба лазерного импульса, регистрируют интенсивность импульса светового излучения продуктов обработки ткани, по пиковому значению которого определяют тип обрабатываемой ткани. Указанная задача также достигается тем, что устройство для обработки твердых тканей зуба лазерным излучением, состоящее из последовательно расположенных вдоль оптической оси импульсного лазера, а также средства доставки и фокусировки лазерного излучения, содержит фотоприемник, вход которого оптически сопряжен с фокальной плоскостью фокусирующей системы, и измеритель амплитуды электрических импульсов, вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен со входом устройства индикации, причем фотоприемник установлен таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей

системы угла альфа, удовлетворяющий условию  $\alpha > \arctan(D/2f)$ , где D - световой диаметр выходного окна фокусирующей системы, а f - ее фокусное расстояние. 2 с. и 4 з.п.ф., 5 ил.



в) фиг.1



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(19) **RU** <sup>(11)</sup> **2 089 127** <sup>(13)</sup> **C1**  
(51) Int. Cl.<sup>6</sup> **A 61 C 5/00, A 61 N 5/06**

(12) **ABSTRACT OF INVENTION**

(21), (22) Application: 94040344/14, 02.11.1994

(46) Date of publication: 10.09.1997

(71) Applicant:  
**Al'tshuler Grigorij Borisovich,**  
**Erofeev Andrej Viktorovich**

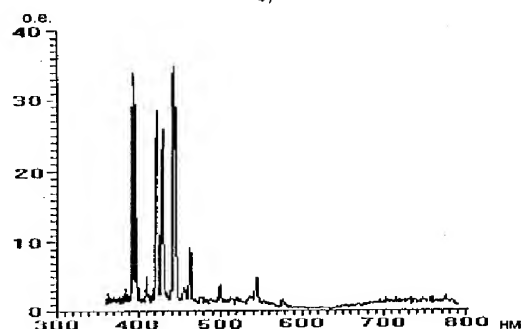
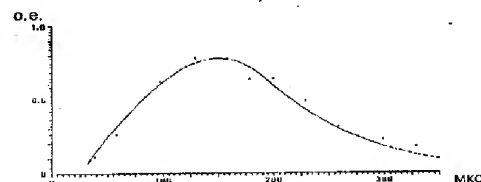
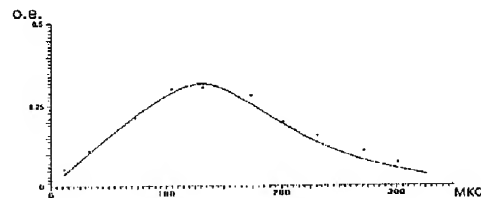
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(73) Proprietor:  
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**Erofeev Andrej Viktorovich**

(54) **METHOD OF TREATMENT OF TOOTH HARD TISSUES BY LASER RADIATION AND DEVICE FOR ITS REALIZATION**

(57) Abstract:

FIELD: medical equipment, applicable in stomatology at treatment of caries and dental prosthetics. SUBSTANCE: the method consists in action of laser pulse on the tooth tissue, pulse intensity of light radiation of tissue treatment products is detected, and the type of tissue to be treated is determined according to the pulse peak amplitude. The device uses a pulsed laser and means for delivery and focusing of laser radiation arranged in succession in the optical axis, photodetector whose input is optically integrated with the focusing system focal plane, and an electric pulse amplitude meter, whose input is electrically coupled to the photodetector output, and the output is electrically coupled to the display unit input; the photodetector is installed in such a manner that the direction of its maximum sensitivity makes up angle  $\alpha$  with the direction of the optical axis at the output of the focusing system; this angle satisfies condition  $\alpha > \arctg(D/2f)$ , where  $D$  - clear aperture of the focusing system output window, and  $f$  - its focal length. EFFECT: reduced danger of laser injury to patient. 6 cl, 5 dwg



b) *фиг.1*

Изобретение относится к медицинской технике и может быть использовано в стоматологии.

Известен способ удаления начальных кариозных повреждений и/или камней зуба (патент USA 4521194, А 61 С 05/00, приоритет 22.12.83), включающий обработку твердых тканей зуба импульсным лазерным излучением. Основным недостатком данного способа является высокая опасность нанесения лазерной травмы при обработке твердых тканей зуба.

Наиболее близким по технической сущности и принятым за прототип является способ лечения неосложненного кариеса (а.с. СССР N 1593669, А 61 С 5/00, приоритет 14.11.85, опубл. 23.09.90 БИ N 35), включающий обработку твердых тканей зуба лазерным излучением с длиной волны 2,94 мкм, длительностью импульсов 100 500 мкс, мощностью 0,5 1,0 Дж/имп, плотностью мощности  $2 \cdot 10^4 \pm 3 \cdot 10$  Вт/см<sup>2</sup>, частотой 1 Гц, экспозицией 3-30 с. Основным недостатком прототипа является опасность нанесения лазерной травмы при обработке тканей зуба, связанная с отсутствием в прототипе процедуры определения типа обрабатываемой ткани.

Известно устройство для обработки твердых тканей зуба лазерным излучением (патент WO 89/08432, А 61 С 5/00, приоритет 10.03.89), включающее последовательно расположенные вдоль оптической оси импульсный лазер и средство доставки излучения к зубу в виде оптического волокна. Основным недостатком данного устройства является высокая опасность нанесения лазерной травмы при обработке твердых тканей зуба.

Наиболее близким по технической сущности и принятым за прототип является устройство для обработки твердых тканей зуба лазерным излучением (патент WO 90/01907, А 61 С 5/00, приоритет 25.08.89), содержащее последовательно расположенные вдоль оптической оси импульсный лазер, а также средство доставки и фокусировки лазерного излучения, включающее отрезок оптического волокна, вход которого оптически сопряжен с выходом лазера, и фокусирующей систему, вход которой оптически сопряжен с выходом оптического волокна, а выход является выходом устройства. Основным недостатком прототипа является опасность нанесения лазерной травмы при обработке тканей зуба, связанная с отсутствием в прототипе системы определения типа обрабатываемой ткани.

Задачей, на решение которой направлено заявляемое изобретение, является снижение опасности нанесения пациенту лазерной травмы за счет обеспечения возможности определения типа обрабатываемой ткани.

Указанная задача достигается тем, что в способе обработки твердых тканей зуба лазерным излучением, включающем воздействие на ткани зуба лазерного импульса, регистрируют интенсивность импульса светового излучения продуктов обработки ткани, по пиковому значению которой определяют тип обрабатываемой ткани. Для повышения достоверности определения типа обрабатываемой ткани интенсивность указанного светового излучения регистрируют в спектральном

диапазоне 350 500 нм. С той же целью одновременно с регистрацией интенсивности импульса светового излучения измеряют временную задержку между лазерным и световым импульсами, по величине которой уточняют тип обрабатываемой ткани.

Указанная задача также достигается тем, что устройство для обработки твердых тканей зуба лазерным излучением, состоящее из последовательно расположенных вдоль оптической оси импульсного лазера, а также средства доставки и фокусировки лазерного излучения, содержит фотоприемник, вход которого оптически сопряжен с фокальной плоскостью фокусирующей системы, и измеритель амплитуды электрических импульсов, вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен со входом устройства индикации, причем фотоприемник установлен таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол альфа, удовлетворяющий условию  $\alpha > \arctg(D/2f)$ , где D световой диаметр выходного окна фокусирующей системы, а f ее фокусное расстояние. Для повышения достоверности определения типа обрабатываемой ткани вход фотоприемника оптически сопряжен с фокальной плоскостью фокусирующей системы через спектральный фильтр с полосой пропускания 350 500 нм. С той же целью устройство дополнительно содержит фоторегистратор и блок измерения временных интегралов, причем вход фоторегистратора оптически сопряжен с выходом лазера, а выход электрически сопряжен со одним из входов блока измерения временных интервалов, второй вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен со входом устройства индикации.

На фиг. 1 представлены: (а) импульс светового излучения продуктов обработки, возникающий при лазерном разрушении дентина, (б) импульс светового излучения продуктов обработки, возникающий при лазерном разрушении эмали, (в) спектральная зависимость отношения импульсов светового излучения продуктов обработки, возникающих при лазерном разрушении дентина и эмали; на фиг. 2

временные диаграммы: (а) интенсивности лазерного импульса, (б) плотности энергии лазерного излучения, падающего на обрабатываемую поверхность, а также интенсивности импульсов светового излучения продуктов обработки, возникающих при разрушении дентина (в) и эмали (г); на фиг. 3 схема устройства по п. 4 формулы изобретения для реализации способа по п. 1 формулы; на фиг. 4 схема устройства по п. 5 формулы изобретения для реализации способа по п. 2 формулы; на фиг. 5 схема устройства по п. 5 формулы изобретения для реализации способа по п. 3 формулы.

Как известно, к твердым тканям зуба относится эмаль и дентин. Пороги разрушения этих тканей лазерным излучением различаются в несколько раз, причем порог разрушения дентина ниже, чем порог разрушения эмали. При обработке твердых тканей зуба лазерным излучением на



обрабатываемой поверхности в видимом диапазоне спектра возникает свечение продуктов обработки в виде эрозийного факела, что делает невозможным визуальный контроль состояния облучаемой поверхности ткани и определение ее типа. Другими словами, врач не в состоянии определить воздействует лазерное излучение на эмаль или дентин непосредственно в процессе обработки. При этом процедура лазерной обработки твердых тканей зуба сопряжена с опасностью нанесения лазерной травмы дентина или пульпы в том случае, если импульсное излучение лазера с энергией превышает порог разрушения эмали попадает на дентин. Основным фактором риска является контузия тканей импульсом отдачи, возникающим при значительном превышении энергии лазерного излучения, падающего на обрабатываемую ткань, над значением порога разрушения. Проведенные авторами экспериментальные исследования режимов обработки твердых тканей зуба лазерным излучением (G.B.Altshuler, A.V.Belikov, A.V.Erofeev "The damage of hard tooth tissues with laser pulses of different duration", Proceeding 4th International Conference on Laser Application in Life Science, 1992, p.114) позволили выявить приемлемый с точки зрения безопасности процедуры лазерной обработки зуба диапазон значений плотности энергии лазерного излучения. Для эмали допустимым является десятикратное превышение плотности энергии лазерного излучения над пороговым разрушением. Для дентина безопасный диапазон примерно вдвое уже (т.е. допустимо лишь пятикратное превышение плотности энергии лазерного излучения над порогом), что объясняется непосредственной близостью дентина к пульпе.

Для уменьшения опасности нанесения травмы пациенту при обработке твердых тканей зуба лазерным излучением авторы предлагают идентифицировать тип обрабатываемой ткани (эмаль, дентин) по характеристикам импульсов светового излучения продуктов обработки ткани. Авторами экспериментально показано, что пиковая (максимальная) интенсивность импульса светового излучения продуктов обработки, возникающего при разрушении дентина (фиг. 1а), существенно (в несколько раз) отличается от пиковой интенсивности импульса светового излучения продуктов обработки, возникающего при разрушении эмали (фиг. 1б). Таким образом, введение в способ обработки тканей зуба операции регистрации интенсивности импульса светового излучения продуктов обработки, по пиковому значению которой можно определить тип обрабатываемой ткани, дает возможность снижать в случае необходимости энергию излучения, не допуская нанесения лазерной травмы пациенту.

Авторами экспериментально показано также, что наиболее существенное различие пиковых интенсивностей импульсов светового излучения продуктов обработки, возникающих при разрушении эмали и дентина, наблюдается в спектральном диапазоне 350-500 нм. На фиг. 1в изображен график отношения спектров светового излучения продуктов обработки дентина и эмали. Из

чертежа видно, что значение отношения максимально именно в спектральном диапазоне 350-500 нм, таким образом, спектральная селекция светового излучения продуктов обработки дает возможность повысить достоверность определения типа обрабатываемой ткани.

При воздействии на ткани зуба импульсного лазерного излучения, энергия которого превышает необходимое для их разрушения значение, наблюдается временная задержка между началом воздействия лазерного импульса и появлением импульса светового излучения продуктов обработки, свидетельствующего о начале разрушения ткани. Величина этой задержки определяется двумя факторами: интенсивностью лазерного излучения на поверхности обрабатываемой ткани и величиной порога ее разрушения (т.е. типом обрабатываемой ткани). На фиг. 2 представлены поясняющие временные диаграммы интенсивности лазерного импульса (а), плотности энергии лазерного излучения, падающего на обрабатываемую поверхность (б), интенсивности импульсов светового излучения продуктов обработки, возникающих при разрушении дентина (в) и эмали (г). На фиг. 2б пунктиром показаны уровни плотности энергии лазерного излучения, соответствующие порогам разрушения эмали и дентина. На фиг. 2в, г видно, что импульс светового излучения продуктов обработки дентина имеет меньшую задержку  $t_d$  относительно начала лазерного импульса, чем импульс светового излучения продуктов обработки эмали  $t_z$ . Таким образом, измерение временных задержек импульсов светового излучения продуктов обработки относительно начала лазерного импульса предоставляет возможность уточнения типа обрабатываемой ткани.

По сведениям авторов совокупность изложенных в формуле изобретения признаков является новой, а само техническое решение удовлетворяет критерию "изобретательский уровень".

Заявляемый способ по п. 1 формулы изобретения может быть реализован, например, с помощью устройства, схема которого представлена на фиг. 3. На чертеже показаны последовательно расположенные вдоль оптической оси лазер 1, средство доставки и фокусировки лазерного излучения 2, вход которого оптически сопряжен с выходом лазера, включающее оптическое волокно 3 и фокусирующую систему 4, а также фотоприемник 5, вход которого оптически сопряжен с фокальной плоскостью фокусирующей системы, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы

угол  $\alpha$  удовлетворяющий условию:  $\alpha > \arctg(D/2f)$ , где  $D$  - световой диаметр выходного окна фокусирующей системы,  $f$  - ее фокусное расстояние, измеритель амплитуды электрических импульсов 6, вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен со входом устройства индикации 7. Заявляемый способ по п. 2 формулы изобретения может быть реализован, например, с помощью устройства, схема

которого представлена на фиг. 4. На чертеже показаны лазер 1, средство доставки лазерного излучения от лазера к зубу 2, вход которого оптически сопряжен с выходом лазера, включающее оптическое волокно 3 и фокусирующую систему 4, фотоприемник 5, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол  $\alpha$  удовлетворяющий условию:  $\alpha > \arctg(D/2f)$ , где  $D$  световой диаметр выходного окна фокусирующей системы,  $f$  ее фокусное расстояние, а вход оптически сопряжен с фокальной плоскостью фокусирующей системы через спектральный фильтр 8 с полосой пропускания 350 500 нм, измеритель амплитуды электрических импульсов 6, выход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен со входом устройства индикации 7. Заявляемый способ по п.3 формулы изобретения может быть реализован, например, с помощью устройства, схема которого представлена на фиг. 5. на чертеже показаны лазер 1, средство доставки лазерного излучения от лазера к зубу 2, вход которого оптически сопряжен с выходом лазера, включающее оптическое волокно 3 и фокусирующую систему 4, фотоприемник 5, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол  $\alpha$  удовлетворяющий условию:  $\alpha > \arctg(D/2f)$ , где  $D$  световой диаметр выходного окна фокусирующей системы,  $f$  ее фокусное расстояние, измеритель амплитуды электрических импульсов 6, вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен со входом устройства индикации 7, а также блок измерения временных интервалов 9 и фоторегистратор 10, причем вход фоторегистратора оптически сопряжен с выходом лазера, а выход электрически сопряжен со одним из входов блока измерения временных интервалов, второй вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен со входом устройства индикации.

Пример конкретной реализации заявляемого способа состоит в следующем:

Перед началом обработки твердых тканей зуба излучением проводят калибровку измерительного тракта устройства. Для этого устанавливают уровень энергии измерительного лазера 1, превышающий значение, соответствующее порогу разрушения эмали. После этого излучение, генерируемое импульсным лазером, через средство доставки 2, включающее оптическое волокно 3 и фокусирующую систему 4, направляют на обрабатываемую поверхность калибровочного образца дентина. Одновременно с этим фоторегистратором 10 регистрируют лазерный импульс в блоке измерения временных интервалов 9 фиксируют момент времени, соответствующий его началу. При разрушении дентина возникает импульс светового излучения продуктов его обработки. Этот световой импульс регистрируют

фотоприемником 5, оптически сопряженным с обрабатываемой зоной. Измерителем амплитуды электрических импульсов 6 фиксируют момент времени, соответствующий началу импульса светового излучения продуктов обработки дентина, и измеряют пиковую интенсивность этого импульса. В блоке измерения временных интервалов определяют задержку начала импульса светового излучения продуктов обработки дентина относительно начала лазерного импульса. В спектральном фильтре 8 производят спектральное преобразование светового излучения продуктов обработки дентина и измеряют пиковую интенсивность импульса светового излучения продуктов обработки дентина в спектральном диапазоне от 350 до 500 нм. Значения пиковой интенсивности импульса светового излучения продуктов обработки дентина, задержки этого импульса относительно начала лазерного импульса и пиковой интенсивности импульса светового излучения продуктов обработки дентина в указанном спектральном диапазоне фиксируют в устройстве индикации 7 в качестве эталонных для дентина. После этого излучение, генерируемое импульсным лазером, через средство доставки направляют на обрабатываемую поверхность калибровочного образца эмали. Одновременно с этим регистрируют лазерный импульс и фиксируют момент времени, соответствующий его началу. При разрушении эмали возникает импульс светового излучения продуктов ее обработки. Этот световой импульс регистрируют фотоприемником. Фиксируют момент времени, соответствующий началу импульса светового излучения продуктов обработки эмали, и измеряют пиковую интенсивность этого импульса. Определяют задержку начала импульса светового излучения продуктов обработки эмали относительно начала лазерного импульса. Производят спектральное преобразование светового излучения продуктов обработки эмали и измеряют пиковую интенсивность импульса светового излучения продуктов обработки эмали в спектральном диапазоне от 350 до 500 нм. Значения пиковой интенсивности импульса светового излучения продуктов обработки эмали, задержки этого импульса относительно начала лазерного импульса и пиковой интенсивности импульса светового излучения продуктов обработки эмали в указанном спектральном диапазоне фиксируют в устройстве индикации 7 в качестве эталонных для эмали.

После того, как получены эталонные значения пиковых интенсивностей импульсов светового излучения продуктов обработки эмали и дентина, пиковых интенсивностей импульсов светового излучения продуктов обработки эмали и дентина в спектральном диапазоне 350 500 нм и задержек импульсов светового излучения продуктов обработки эмали и дентина относительно начала лазерного импульса, импульсное лазерное излучение направляют на обрабатываемую поверхность твердой ткани зуба. Регистрируют импульс светового излучения продуктов обработки твердой ткани зуба лазерным излучением. Измеряют пиковую интенсивность данного импульса и сравнивают ее с эталонными значениями

пиковых интенсивностей для эмали и дентина. В том случае, если измеренная пиковая интенсивность импульса светового излучения продуктов ткани I удовлетворяет условию:  $I > (I_3 + I_d)/2$ , где  $I_3$ ,  $I_d$  эталонные значения пиковой интенсивности импульсов светового излучения продуктов обработки, возникающих при лазерном разрушении эмали и дентина, соответственно, то обрабатываемую твердую ткань зуба определяют как эмаль, в противном случае как дентин.

Для повышения достоверности определения типа обрабатываемой ткани измеряют пиковое (максимальное) значение интенсивности импульса светового излучения продуктов обработки в спектральном диапазоне от 350 до 500 нм. Сравнивают ее с эталонными значениями пиковых интенсивностей импульсов светового излучения продуктов обработки эмали и дентина в указанном спектральном диапазоне. В этом случае, если измеренная пиковая интенсивность импульса светового излучения продуктов обработки ткани в спектральном диапазоне от 350 до 500 нм  $I^s$  удовлетворяет условию:

$$I^s < (I_3^s + I_d^s)/2 \quad \text{где } I_3^s, I_d^s$$

эталонные значения пиковой интенсивности импульсов светового излучения продуктов обработки, возникающих при лазерном разрушении эмали и дентина, соответственно, то обрабатываемую твердую ткань зуба определяют как дентин, в противном случае как эмаль.

Для уточнения типа обрабатываемой ткани зуба с помощью фоторегистратора регистрируют лазерный импульс и фиксируют момент его начала, измеряют задержку между началом лазерного импульса и началом импульса светового излучения продуктов обработки ткани. Сравнивают ее величину с эталонными значениями задержек для эмали и дентина. В этом случае, если измеренная задержка импульса светового излучения продуктов обработки ткани относительно лазерного импульса  $\tau$  удовлетворяет условию:  $\tau > (\tau_3 + \tau_d)/2$ , где  $\tau_3$ ,  $\tau_d$  эталонные значения задержек акустических импульсов, возникающих при лазерном разрушении эмали и дентина, соответственно, то обрабатываемую твердую ткань зуба определяют как эмаль, в противном случае как дентин.

Безопасность процедуры обработки твердых тканей зуба лазерным излучением обеспечивается возможностью управления энергией генерации лазера в соответствии с информацией о типе обрабатываемой ткани.

Для получения информации о типе обрабатываемой ткани необходимо регистрировать световое излучение продуктов обработки, возникающие при разрушении ткани лазерным импульсом. Однако, при воздействии на обрабатываемую ткань лазерным излучением продукты обработки ткани взаимодействуют с лазерным излучением не только в зоне обработки (в фокальной плоскости фокусирующей системы), но и в не ее в тех областях, где лазерный пучок пересекается с эрозионным факелом. В результате такого взаимодействия интенсивность и спектр

светового излучения продуктов обработки ткани изменяются неконтролируемым образом. Авторами показано, что для регистрации светового излучения продуктов обработки ткани, несущего информацию об ее типе (эмаль, дентин), необходимо не только обеспечить оптическое сопряжение фотоприемника с зоной облучения ткани (фокальная плоскость фокусирующей системы), но и не допустить попадания на фотоприемник светового излучения той части эрозионного факела, которая взаимодействует с лазерным пучком. Последнее условие можно выполнить в том случае, если направление максимальной чувствительности фотоприемника составляет с направлением оптической оси на выходе фокусирующей системы

угол  $\alpha$  удовлетворяющий условию  $\alpha > \arctg(D/2f)$ , где D световой диаметр выходного окна фокусирующей системы, а f ее фокусное расстояние. При этом на фотоприемник не попадает световое излучение продуктов обработки ткани, которое возникает внутри эрозионного факела при взаимодействии с лазерным излучением.

Таким образом, предлагаемая в настоящем изобретении конструкция устройства, содержащего фотоприемник, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол  $\alpha$  удовлетворяющий условию: направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол  $\alpha$  удовлетворяющий условию  $\alpha > \arctg(D/2f)$ , где D световой диаметр выходного окна фокусирующей системы, а f ее фокусное расстояние, является необходимым условием достижения решаемой задачи. Диаграмма направленности фотоприемника на фиг. 3 5 условно показана штриховкой.

По п. 4 формулы изобретения устройство содержит (см. фиг. 3) импульсный лазер 1, выход которого оптически сопряжен со средством доставки излучения от лазера к зубу 2, содержащим последовательно расположенные отрезок оптического волокна 3 и фокусирующую систему 4. Фотоприемник 5 установлен таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол, удовлетворяющий заявляемому соотношению, а выход фотоприемника через пиковый детектор 6 электрически сопряжен с устройством индикации 7.

По п. 5 формулы изобретения устройство дополнительно содержит (см. фиг. 4) спектральный фильтр 8 с полосой пропускания 350 500 нм, установленный таким образом, что его вход оптически сопряжен с фокальной плоскостью фокусирующей системы 4, а выход оптически сопряжен со входом фотоприемника 5.

По п. 6 формулы изобретения устройство дополнительно содержит (см. фиг. 5) блок измерения временных интервалов 9 и фоторегистратор 10, причем вход фоторегистратора оптически сопряжен с выходом лазера 1, а выход электрически сопряжен со одним из входов блока

измерения временных интервалов, второй вход которого электрически сопряжен с выходом фотоприемника 5, а выход электрически сопряжен со входом устройства индикации 7.

Пример конкретной реализации заявляемого устройства состоит в следующем:

В качестве источника излучения выбран импульсный лазер 1 на ИСГГ:Cr,Er. Средство доставки излучения от лазера к зубу 2 выполнено в виде оптически сопряженных отрезка сапфирового волокна 3 и фокусирующей системы 4 со световым диаметром выходного окна 2 мм и фокусным расстоянием 25 мм, причем оптический вход средства доставки излучения оптически сопряжен с выходом лазера. На расстоянии 45 мм от заднего фокуса фокусирующей системы расположен фотоприемник 5 марки ФД24К, установленный таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол  $28^\circ$ . Выход фотоприемника электрически сопряжен через измеритель амплитуды электрических импульсов (осциллограф Ц9-8) 6 с индикатором 7, в качестве которого выбран цифровой вольтметр В4-17.

Дополнительно устройство содержит спектральный фильтр с полосой пропускания 350 500 нм, выполненный в виде плоскопараллельной пластины и установленный таким образом, что его выход оптически сопряжен с фокальной плоскостью фокусирующей системы 4, а выход оптически сопряжен с фотоприемником 5.

Также устройство дополнительно содержит фоторегистратор 10 на базе фотодиода ФД34, оптически сопряженный с выходом лазера 1 и электрически сопряженный с одним из входов измерителя временных интервалов 9 на базе цифровой осциллографа С9-16. Второй вход измерителя временных интервалов электрически сопряжен с выходом фотоприемника 5. На выходе измерителя временных интервалов задержка между началом лазерного импульса, регистрируемого фоторегистратором, и началом импульса светового излучения продуктов лазерной обработки твердой ткани зуба, регистрируемого фотоприемником, преобразуется в электрический сигнал, амплитуда которого пропорциональна величине временной задержки. Выход измерителя временных интервалов электрически сопряжен с индикатором 7.

Таким образом, на основании вышеизложенного заявляемая совокупность

признаков в способе и устройстве позволяет решить задачу, а именно снизить опасность нанесения травмы пациенту при лазерной обработке твердых тканей зуба при лечении кариеса и протезировании.

### Формула изобретения:

1. Способ обработки твердых тканей зуба лазерным излучением, включающий воздействие на ткани зуба лазерным импульсом, отличающийся тем, что регистрируют интенсивность импульса светового излучения продуктов обработки ткани, по пиковому значению которого определяют тип обрабатываемой ткани.

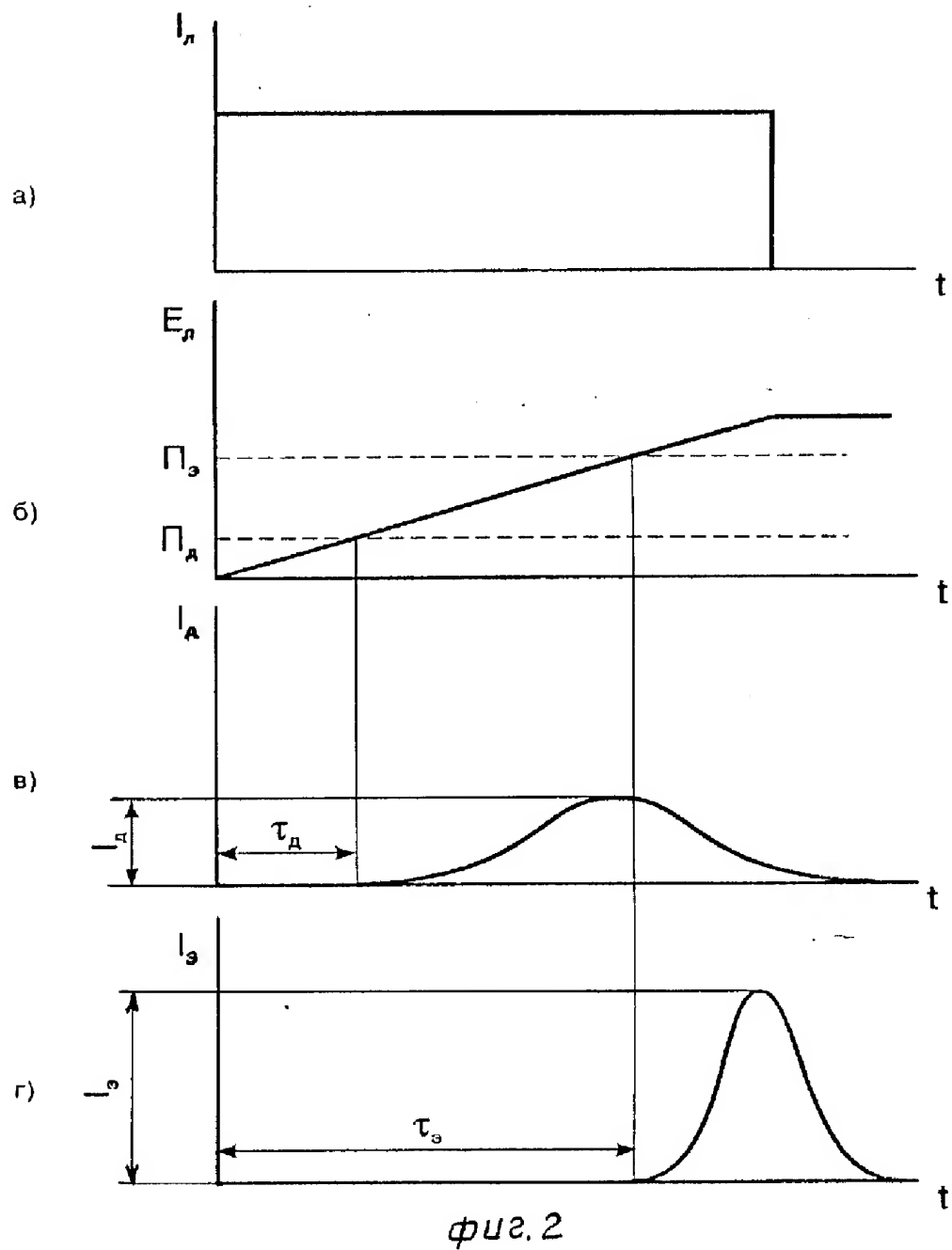
2. Способ по п.1, отличающийся тем, что интенсивность светового излучения регистрируют в спектральном диапазоне 350 500 нм.

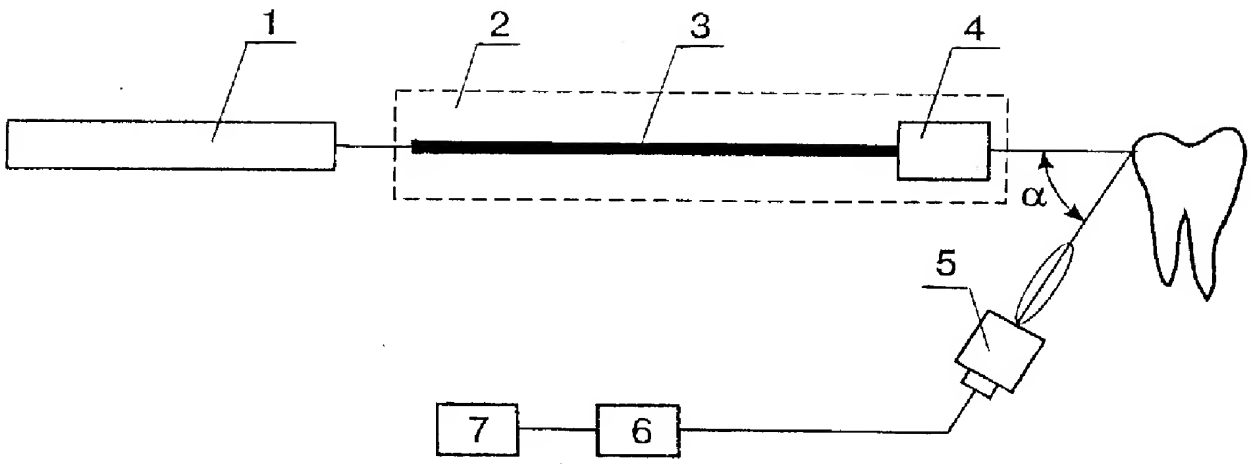
3. Способ по п.1, отличающийся тем, что одновременно с регистрацией интенсивности импульса светового излучения измеряют временную задержку между лазерными световыми импульсами, по величине которой уточняют тип обрабатываемой ткани.

4. Устройство для обработки твердых тканей зуба лазерным излучением, состоящее из последовательно расположенных вдоль оптической оси импульсного лазера, а также средства доставки и фокусировки лазерного излучения, отличающееся тем, что оно содержит фотоприемник, вход которого оптически сопряжен с фокальной плоскостью фокусирующей системы, и измеритель амплитуды электрических импульсов, вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен с входом устройства индикации, причем фотоприемник установлен так, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе фокусирующей системы угол  $\alpha$ , удовлетворяющий условию  $\alpha > \arctg(D/2f)$ , где D световой диаметр выходного окна фокусирующей системы; f ее фокусное расстояние.

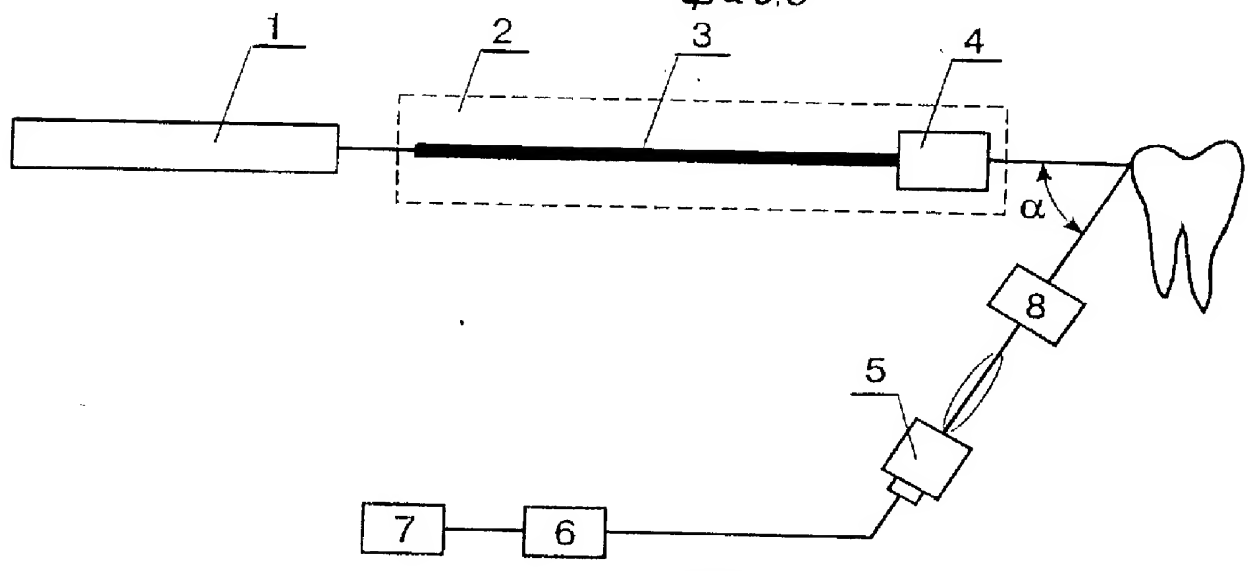
5. Устройство по п.4, отличающееся тем, что вход фотоприемника оптически сопряжен с фокальной плоскостью фокусирующей системы через спектральный фильтр с полосой пропускания 350 500 нм.

6. Устройство по п. 4, отличающееся тем, что устройство дополнительно содержит фоторегистратор и блок измерения временных интервалов, причем вход фоторегистратора оптически сопряжен с выходом лазера, а выход электрически сопряжен с одним из входов блока измерения временных интервалов, второй вход которого электрически сопряжен с выходом фотоприемника, а выход электрически сопряжен с входом устройства индикации.





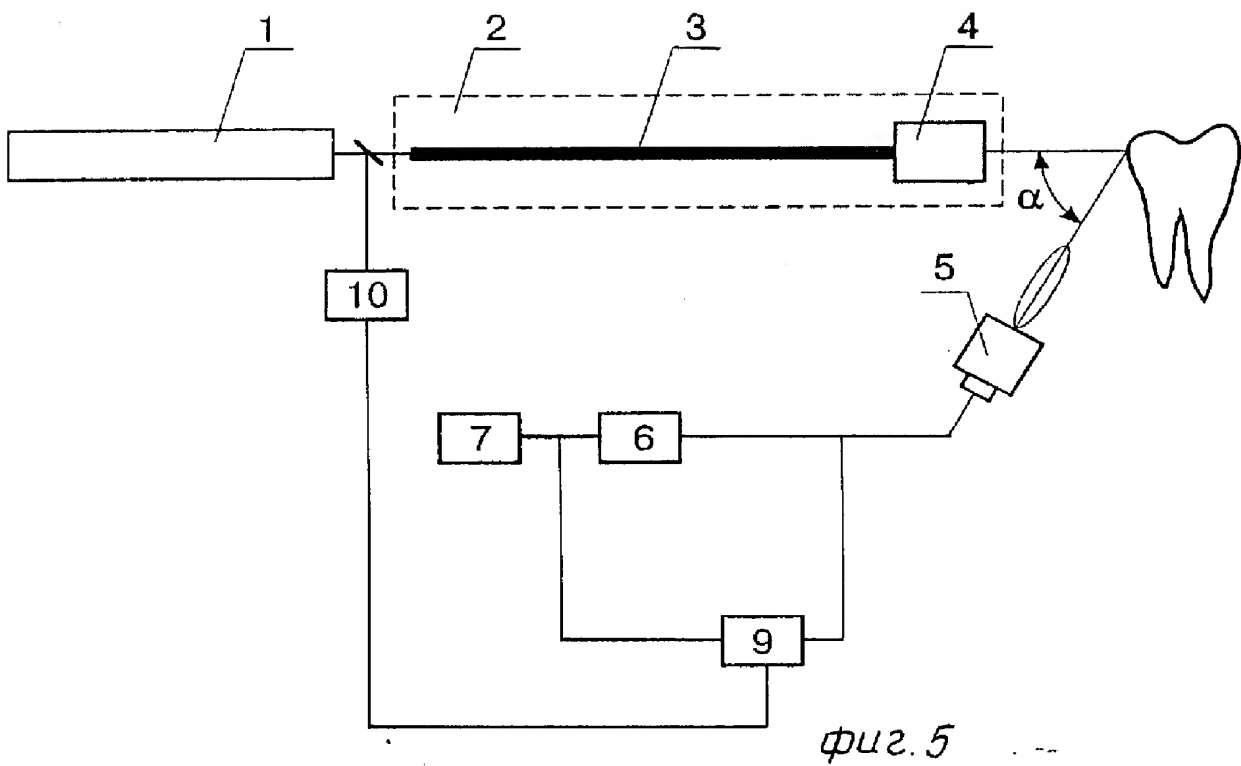
фиг.3



фиг.4

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RU 2089127 C1



RU 2089127 C1

RU 2089127 C1

# APPARATUS FOR LASER TREATMENT OF BIOLOGICAL TISSUES (ALTERNATIVE EMBODIMENTS)

**Publication number:** RU2096051 (C1)

**Publication date:** 1997-11-20

**Inventor(s):** ALTSHULER GRIGORIY B [RU]

**Applicant(s):** ALTSHULER GRIGORIY B [RU]

**Classification:**

- **international:** **A61B18/20; A61B18/22; A61C1/00; A61C3/02; A61C5/00; A61B17/00; A61B18/20; A61C1/00; A61C3/02; A61C5/00; A61B17/00; (IPC1-7): A61N5/06; A61C5/00**

- **European:** A61C1/00L; A61B18/22

**Application number:** RU19950102749 19950224

**Priority number(s):** RU19950102749 19950224

**Also published as:**

WO9625979 (A1)

US5873875 (A)

JP11502130 (T)

EP0844008 (A1)

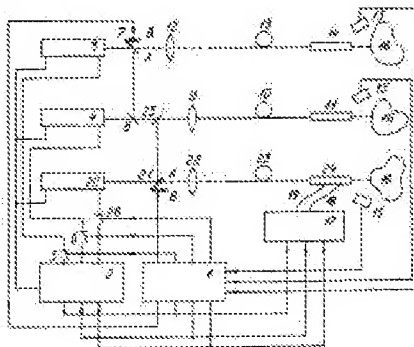
EP0844008 (A4)

more >>

Abstract not available for RU 2096051 (C1)

Abstract of corresponding document: **WO 9625979 (A1)**

The devices, comprising two or three pulse lasers (3, 4, 20), are provided with a system for the automated optimisation of the parameters pertaining to the radiation of the two lasers and to the type and method of treatment applied to each type of biological tissue. The outputs from at least one receiver (15) for receiving data on the condition of the biological tissue (16) being treated are connected to the inputs of the control unit (1) whose output signals are applied to electronic switches (5, 6, 26) incorporated in the links between each laser (3, 4, 20) and a power supply unit (2). The devices also include a controllable irrigation system (17) for irrigating the treatment zone and a mixing system for mixing the laser beams. The latter system comprises reflecting mirrors (7, 21) and selectively reflecting mirrors (8, 25) and makes it possible to produce independent radiation outputs.



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(19) **RU** <sup>(11)</sup> **2 096 051** <sup>(13)</sup> **C1**  
(51) МПК<sup>6</sup> **A 61 N 5/06, A 61 C 5/00**

РОССИЙСКОЕ АГЕНТСТВО  
ПО ПАТЕНТАМ И ТОВАРНЫМ ЗНАКАМ

(12) **ОПИСАНИЕ ИЗОБРЕТЕНИЯ К ПАТЕНТУ РОССИЙСКОЙ ФЕДЕРАЦИИ**

(21), (22) Заявка: 95102749/14, 24.02.1995

(46) Дата публикации: 20.11.1997

(56) Ссылки: WO, патент, 90/12548, кл. A 61 N 5/00, 1990.

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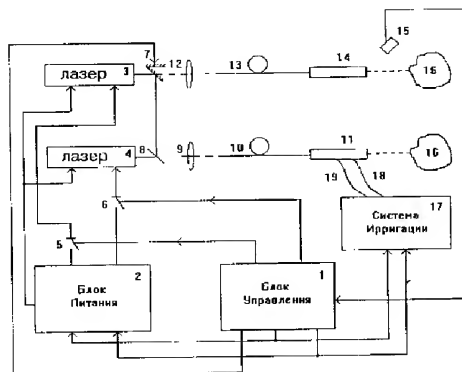
Альтшулер Григорий Борисович

(54) **УСТРОЙСТВО ДЛЯ ЛАЗЕРНОЙ ОБРАБОТКИ БИОЛОГИЧЕСКОЙ ТКАНИ (ЕГО ВАРИАНТЫ)**

(57) Реферат:

Использование: изобретение относится к медицинской технике и может быть использовано в хирургии, ортопедии и стоматологии. Сущность изобретения: автоматический контроль состояния обрабатываемой биоткани и управление параметрами излучений лазеров достигаются благодаря совокупности введенных в устройства хотя бы одного приемника информации о состоянии биоткани, выход которого соединен с входом блока управления, и электронных ключей, установленных в цепях питания лазеров и управляемых выходными сигналами блока управления. Наличие в одном устройстве двух или трех лазеров с различными длинами волн излучений и независимых выходов, а также возможность смешивания излучений этих лазеров обеспечивает возможность требуемого, ориентированного на

минимальную инвазивность режима обработки. 5 ил.



Фиг. 1



(19) **RU** <sup>(11)</sup> **2 096 051** <sup>(13)</sup> **C1**  
 (51) Int. Cl.<sup>6</sup> **A 61 N 5/06, A 61 C 5/00**

RUSSIAN AGENCY  
FOR PATENTS AND TRADEMARKS

(12) **ABSTRACT OF INVENTION**

(21), (22) Application: 95102749/14, 24.02.1995

(46) Date of publication: 20.11.1997

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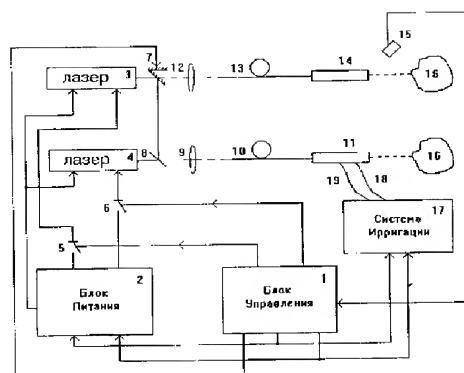
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(54) **APPARATUS FOR LASER TREATMENT OF BIOLOGICAL TISSUES (ALTERNATIVE EMBODIMENTS)**

(57) Abstract:

FIELD: medical engineering; surgery; orthopedics; stomatology. SUBSTANCE: proposed apparatus comprises at least one receiver of information about condition of biotissue to be automatically controlled. Receiver output is connected with input of control unit. Apparatus further comprises electronic switches arranged in current supply circuits of lasers and controlled by output signals issued by control unit. Finally, apparatus comprises two or three lasers emitting radiations at different wavelengths and having independent outputs. EFFECT: improved design. 7 cl, 5 dwg



Фиг. 1

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Изобретение относится к медицинской технике и может быть использовано в хирургии, ортопедии и стоматологии для обработки мягких и твердых биологических тканей.

Известно устройство для обработки тканей зуба лазерным излучением (патент WO 90/01907, А 61 С 5/00, дата публикации 08.03.90), содержащее последовательно расположенные вдоль оптической оси импульсный лазер и средство доставки излучения к зубу, включающее отрезок оптического волокна, вход которого оптически сопряжен с выходом лазера, и наконечник, вход которого оптически сопряжен с выходом оптического волокна, а выход является выходом устройства. Причем в качестве лазера может быть использован как неодимовый, так и гольмиевый или эрбиевый лазеры.

Основным недостатком данного устройства является невозможность быстрой замены одного лазера на другой в зависимости от типа обрабатываемой ткани, а также высокая опасность нанесения лазерной травмы.

Известно также лазерное устройство для лечения зубов, которое является наиболее близким по технической сущности и принято за прототип (патент WO 90/12546, А 62 5/00 дата публикации 01.11.90).

Это устройство содержит блок управления, два импульсных лазера, оптические оси которых параллельны, расположенные на оптической оси второго лазера, фокусирующую систему и отрезок оптического волокна с наконечником. На оптических осях обоих лазеров расположены под углом 45°С к осям зеркала, оптически сопряженные между собой, фокусирующей системой и оптическим волокном. Зеркало, расположенное на оси первого лазера, отражательное, а на оси второго лазера дихроичное, т.е. селективно отражательное для длины волны излучения первого лазера и прозрачное для длины волны излучения второго.

Основным недостатком прототипа является недостаточная эффективность его применения при переходе от режима одного типа обработки к другому и опасность нанесения травмы, связанная с отсутствием системы определения вида обрабатываемой ткани.

Задача, на решение которой направлено заявляемое изобретение, заключается в создании устройства для лазерной обработки биологической ткани, выполняющего все виды лазерных операций в хирургии, ортопедии и стоматологии, с обеспечением при этом возможности быстрого перехода от одного типа обработки к другому и минимальной инвазивности.

Указанная задача решается при осуществлении изобретения за счет достижения технического результата, заключающегося в оптимизации режимов обработки и параметров лазерного излучения в зависимости от типа обработки и вида биологической ткани.

Указанный технический результат при осуществлении изобретения достигается тем, что в устройство для лазерной обработки биологической ткани, содержащее блок управления, выходы которого соединены с

блоком питания лазеров, импульсные лазеры, оптические оси которых параллельны, оптически сопряженные отражательные и селективно отражательное для длины волны первого лазера и прозрачное для длины волны второго лазера зеркала, которые расположены на осях первого и второго лазеров соответственно, установленные на оптической оси второго лазера фокусирующую систему и оптическое волокно с наконечником, выход которого является оптическим выходом устройства, введен хотя бы один приемник информации о состоянии биологической ткани, вход которого сопряжен с местом воздействия на ткань, а выход соединен с входом блока управления, выходы которого соединены с входами электронных ключей, установленных в цепях соединения каждого лазера с блоком питания. Отражательное зеркало установлено с возможностью вывода его из хода излучения, а на оптической оси первого лазера последовательно по ходу излучения расположена фокусирующая система и оптическое волокно с наконечником, выход которого является другим оптическим выходом устройства.

Более эффективно указанный технический результат достигается тем, что в устройство для лазерной обработки биологической ткани, содержащее блок управления, выходы которого соединены с блоком питания лазеров, импульсные лазеры, оптические оси которых параллельны, оптически сопряженные отражательное и селективно отражательное для длины волны первого лазера и прозрачное для длины волны второго лазера зеркала, которые расположены на осях первого и второго лазеров соответственно, установленные на оптической оси второго лазера фокусирующую систему и оптическое волокно с наконечником, выход которого является оптическим выходом устройства, введен третий импульсный лазер, оптическая ось которого параллельна оптическим осям двух других лазеров, а на его оси установлено отражательное зеркало, причем отражательные зеркала установлены с возможностью вывода их из хода излучения. На оптической оси второго лазера за селективным зеркалом установлено второе селективно отражательное для длины волны третьего лазера и прозрачное для длины волны первого и второго лазеров зеркало, оптически сопряженное с отражательным зеркалом, установленным на оси третьего лазера, фокусирующей системой и входом оптического волокна, расположенных на оси второго лазера. Кроме того, на каждой из осей первого и третьего лазеров последовательно по ходу излучения расположены фокусирующая система и оптическое волокно и наконечником, выходы которых являются оптическими входами устройства. Устройство также снабжено хотя бы одним приемником информации о состоянии биологической ткани, вход которого сопряжен с местом воздействия на ткань, а выход соединен с входом блока управления, выходы которого соединены с входами электронных ключей, установленных в цепях соединения каждого лазера с блоком питания.

Приемник информации о состоянии биологической ткани может быть выполнен в

виде спектроанализатора в области 200-1500 нм, вход которого оптически сопряжен с местом воздействия на ткань и состоящего из дисперсионного элемента, линейки фотодетекторов и элемента сравнения.

Приемник информации о состоянии биологической ткани также может быть выполнен в виде фотоэлектрического приемника инфракрасного излучения, вход которого оптически сопряжен с местом воздействия на ткань посредством поворотного зеркала, расположенного на оптической оси лазера между выходным зеркалом лазера и фокусирующей системой через фильтр с полосой пропускания, исключающей попадание на приемник излучения лазера.

Приемник информации о состоянии биологической ткани может быть еще выполнен в виде акустического приемника, установленного таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на входе наконечника угол  $\alpha$ , удовлетворяющий условию:  $11^\circ < \alpha < 86^\circ$ .

Электронный ключ может быть выполнен в виде полупроводникового или электровакуумного переключателя.

Дополнительно устройство снабжено системой орошения зоны обработки, состоящей из резервуара для воды с водяным насосом и воздушного компрессора, соответствующие выходы которых объединены в наконечниках и являются ирригационными выходами устройства, а воздушный компрессор в месте соединения с воздухопроводами снабжен электромагнитными клапанами, подключенными к выходам блока управления.

Известно, что эффективность лазерной обработки биологической ткани с одновременным обеспечением низкой инвазивности (степени некроза) зависит от длины волны и мощности лазерного излучения, энергии и времени лазерного воздействия, а для некоторых видов ткани жидкостного орошения зоны лазерной обработки (см. например Proceeding of Laser-Tissue Interaction V 24-27 January 1994, Los Angeles, California Vol 2134A).

Исследования, проведенные автором, показали, что при этом необходима одновременная оптимизация указанных параметров для каждого вида биоткани. Иными словами, необходимы: возможность выбора оптимальных длин волн излучений лазеров или их смеси, регистрация процесса лазерной деструкции, вида и состояния биоткани и управления длиной волны, мощностью, энергией и временем лазерного действия, система орошения зоны лазерной обработки.

Совокупность введенных в устройство хоты бы одного приемника информации о состоянии обрабатываемой биологической ткани, выход которого соединен с входом блока управления, и электронных ключей, установленных в цепях питания лазеров и управляемых выходными сигналами блока управления, представляют собой систему обратной связи, которая обеспечивает автоматический контроль и оптимальное управление параметрами излучений лазеров в зависимости от вида и состояния обрабатываемой ткани и тем самым

обеспечивает минимальную инвазивность.

Необходимость автоматического контроля и управления вызвана часто возникающей невозможностью визуального определения врачом состояния облучаемой ткани и ее вида.

Наличие двух независимых выходов в одном устройстве благодаря возможности вывода отражательного зеркала из хода излучения первого лазера, а также возможность смешивания излучений двух лазеров повышает эффективность работы при обработке биоткани и обеспечивает снижение некроза.

Наличие в одном устройстве для обработки биологической ткани трех лазеров с различными длинами волн излучений и независимыми выходами и с возможностью смешивания излучений обеспечивает наибольшую мобильность применения устройства и максимально расширяет его возможности. Например, при одновременном воздействии гольмиевым и неодимовым лазерами на обильно кровеносящие органы снимается опасность кровотечения при несанкционированной перфорации крупных кровеносных сосудов. Для смешивания излучения третьего лазера с двумя другими или каждым из них введены отражательное и селективное зеркала, установленные соответственно к осям третьего и второго лазеров, а возможность вывода отражательных зеркал из хода излучения и наличие дополнительных фокусирующих систем и оптических волокон обеспечивает независимость трех оптических выходов устройств.

Дополнительно введенная в устройства система орошения, управляемая электронными клапанами, подключенными к выходам блока управления, обеспечивает оптимальное сочетание режимов облучения и орошения ткани.

Совокупность изложенных в формуле изобретения признаков является новой, а само техническое решение удовлетворяет критерию "изобретательский уровень".

На фиг.1 изображена схема устройства для лазерной обработки биоткани; на фиг. 2 схема устройства при наличии трех лазеров; на фиг. 3 схема вариантов выполнения и расположения приемников информации о состоянии обрабатываемой биоткани; на фиг.4 система орошения зоны обработки; на фиг.5 блок-схема блока управления.

Устройство для лазерной обработки биологической ткани (фиг.1) состоит из блока управления 1, соединенного с ним блока питания 2, импульсных лазеров 3, 4, соединенных с блоком питания через электронные ключи 5, 6, которые подключены к выходам блока управления 1. На оптических соях лазеров 3, 4 расположены соответственно отражательное зеркало 7 и селективное зеркало 8, которые оптически сопряжены между собой и с фокусирующей системой 9 и выходным торцом оптического волокна 10 с наконечником 11, расположенных на оптической оси лазера 4. Селективное зеркало 8 отражательно для излучения с длиной волны лазера 3, но прозрачно для излучения с длиной волны лазера 4. Расположенное на оптической оси лазера 3 отражательное зеркало 7 подключено к выходу блока управления 1 и в

положении А устанавливается под углом  $45^\circ$  к оси, а в положении В параллельно ей. На этой же оси вслед за зеркалом последовательно по ходу излучения расположены фокусирующая система 12 и оптическое волокно 13 с наконечником 14. К входу блока управления 1 подключен электрический выход приемника информации о состоянии биологической ткани 15, вход которого сопряжен с местом воздействия на биоткань 16. Система ирригации 17 подключена к тем же выходам блока управления 1, что и блок питания 2, а ее водяной и воздушный выходы 18 и 19 объединены в наконечнике 11 (14).

На фиг. 2 представлен вариант устройства с тремя лазерами 3, 4, 20. На оптической оси лазера 20 установлено отражательное зеркало 21, которое так же, как и отражательное зеркало 7, подключено к блоку управления 1, и в положении А устанавливается под углом  $135^\circ$  к оптической оси, а в положении В - параллельно ей. На этой же оптической оси расположены фокусирующая система 22 и входной торец оптического волокна 23 и наконечником 24. Между фокусирующей системой 9 и селективным зеркалом 8 установлено второе селективное зеркало 25, которое оптически сопряжено с зеркалом 21, фокусирующей системой 9 и входным торцом оптического волокна 10. Селективное зеркало 25 отражательно для излучения с длиной волны лазера 20, не прозрачно для излучений с длинами волн лазеров 3, 4. Блок питания 2 соединен с лазером 20 через электронный ключ 26.

Разновидностями приемника информации 15 о состоянии биоткани 16 могут быть как спектроанализатор 27 (фиг.3), вход которого оптически сопряжен с местом воздействия на биоткань 16 и состоящий из дисперсионного элемента 28, линейки фотодетекторов 29 и элемента сравнения 30, так и фотоэлектрический приемник инфракрасного излучения 31, оптически сопряженный с местом воздействия на биоткань посредством оптического волокна 13 (10, 23), фокусирующей системы 12 (9, 22) и поворотного зеркала 32, расположенного между фокусирующей системой 12 (9, 22) и зеркалом 8 или непосредственно перед выходным зеркалом лазера 3 (20). Перед оптическим входом фотоэлектрического приемника 31 установлен инфракрасный фильтр 33, полоса пропускания которого исключает попадание на фотоэлектрический приемник 31 излучения лазера. В качестве приемника информации 15 о состоянии биологической ткани 16 может быть и акустический приемник 34, расположенный вблизи места воздействия на ткань так, что направление его максимальной чувствительности составляет с оптической осью излучения на выходе наконечника 11 (14, 24) угол  $\alpha$ , лежащий в пределах от  $11^\circ$  до  $86^\circ$ .

В связи с тем, что число приемников информации о состоянии биоткани может колебаться от одного до девяти (по каждому виду, около каждого наконечника), количество входов блока управления может быть равно девяти.

Система орошения зоны обработки 17, изображенная на фиг.4, состоит из

резервуара для воды с водяным насосом 35, к которому присоединена водопроводная трубка 18, и воздушного компрессора 36. Присоединенные к воздушному компрессору 36 воздухопроводящие трубки 19 снабжены электромагнитными клапанами 37, 38, 39, которые подключены к тем же выходам блока управления 1, что и блок питания 2, через линии задержки 40, 41, 42.

Устройство работает следующим образом. Излучения лазеров 3, 4, 20, в случае нахождения отражательных зеркал 7 и 21 в положении В, пройдя фокусирующие системы 9, 12, 22, оптические волокна 10, 13, 23 и наконечники 11, 14, 24 поступают на оптические выходы устройства.

Если отражательные зеркала 7 и 21 находятся в положении А, излучение лазера 3, отразившись от зеркала 7, попадает на селективное зеркало 8 и, отразившись от него, направляется вдоль оптической оси лазера 4. Аналогично, при наличии лазера 20, излучение лазера 20 отразившись от зеркала 21, а затем от селективного зеркала 25, также направляется вдоль оптической оси лазера 4. В результате, в связи со свойством селективных зеркал 8 и 25, в фокусирующую систему 9 и на оптический выход наконечника 11 могут поступать излучения всех трех лазеров одновременно.

Выбор вида приемника информации 15 о состоянии биоткани 16 зависит от вида ткани и режима обработки, а также от вида наконечника. При работе с неконтактными наконечниками основная часть излучения эрозийного факела, возникающего из-за свечения удаляемых частиц биоткани, лежит в видимой и ближних ультрафиолетовой и инфракрасной областях спектра (200-1500) нм) и является причиной невозможности визуального наблюдения вида и состояния биоткани.

Спектральный состав излучения эрозийного факела зависит от вида биоткани, поэтому необходим спектральный анализ этого излучения, которое попадает на дисперсионный элемент 28 спектроанализатора 27, разлагается в спектр и попадает на линейку фотодетекторов 29, соединенную с элементом сравнения 30. Уровень выходного электрического сигнала элемента сравнения 30 соответствует конкретной комбинации длин волн спектра излучения эрозийного факела. Электрический сигнал от элемента сравнения 30 спектроанализатора 27 поступает на блок управления 1, где вырабатывается сигнал изменения режима и параметров излучения лазеров.

Работа с контактными наконечниками связана с нагреванием лазерным излучением торца рабочего инструмента (волокно или сапфировый наконечник) до температуры, достаточной для разрушения биоткани. Нагрев места воздействия сопровождается возникновением инфракрасного излучения, которое передается по волокну наконечника 11 (14, 24) и оптическому волокну 10 (13, 23) в направлении, обратном ходу лазерного излучения, отражается от поворотного зеркала 32, проходит инфракрасный фильтр 33 и попадает на фотоэлектрический приемник 31. Электрический сигнал с выхода фотоэлектрического приемника 31 поступает в блок управления 1, где в зависимости от

параметров этого сигнала вырабатывается сигнал остановки, продолжения или изменения режима работы лазера.

Экспериментально установлено, что тепловое излучение, возникающее при работе с контактными наконечниками, находится в глубокой инфракрасной области. В этой области чувствительность фотоэлектрических приемников очень мала. Спектральная область излучения лазеров также лежит в инфракрасной области. Поэтому полоса пропускания инфракрасного фильтра 33 согласована со спектральной чувствительностью фотоприемника 31, с окном прозрачности оптического волокна 13 и обеспечивает исключение попадания на фотоприемник 31 излучения лазеров 3, 4, 20.

Продукты лазерного разрушения биоткани разлетаются со сверхзвуковой скоростью, и в следствие резкого изменения давления из-за сопротивления среды генерируется акустическая волна. Для различных тканей амплитуда акустической волны различна. Амплитуда акустической волны регистрируется акустическим приемником 34, электрический сигнал с которого поступает на блок управления 1, где синтезируется сигнал временной остановки излучения или изменения режима работы лазера в зависимости от типа обрабатываемой ткани или в случае превышения энергии лазерного импульса над порогом разрушения биоткани, что влияет на степень лазерного некроза.

Прекращение в случае необходимости режима излучения лазеров в соответствии с сигналами спектроанализатора 27, фотоэлектрического или акустического приемников 31 и 34 происходит с помощью быстродействующих электронных ключей 5, 6, 26. Сигнал с блока управления 1 подается на управляющий вход электронного ключа 5, (6 26) размыкая цепь питания каждого из лазеров. Прекращение импульса излучения эффективно, если время отключения питания меньше длительности импульса излучения. (Длительность импульса излучения может быть 150-500 мкс.). Поэтому в качестве электронного ключа должен использоваться элемент с высоким быстродействием. Такими управляемыми ключами являются полупроводниковые или электровакуумные переключатели, время срабатывания которых не превышает 100 мкс.

Орошение биоткани с помощью системы 17 происходит следующим образом. Из резервуара для воды с водяным насосом 35 вода заполняет водопроводящие трубки 18. В случае необходимости орошения ткани сигналы из блока управления 1 поступают на электромагнитный клапан 37 (38, 39), который открывает поступление воздуха под давлением из воздушного компрессора 36 в воздухопровод 19. Концы водо- и воздухопроводящих трубок 18 и 19 расположены в наконечниках 11 (14, 24) так, что поступление воды на ирригационные выходы устройства происходит при подаче воздуха по принципу пульверизатора.

Сигналы из блока управления 1 поступают на электромагнитные клапаны 37 (38, 39) через линии задержки 40 (41, 42) одновременно с сигналами запуска импульсов генерации лазеров 3 (4, 20).

Орошение биоткани водой должно происходить в промежутках между

импульсами излучения лазеров (с целью избежать нежелательное рассеяние излучения и повысить эффективность орошения), поэтому длительность времени задержки линий задержки 40 (42, 42) равна временно длительности импульсов излучения лазеров с учетом времени поступления воздуха к концам трубок 19.

Пример конкретной реализации заявляемых устройств состоит в следующем. Блок управления 1 (фиг.5) состоит из усилителя входных сигналов с интегратором (см. Масленников В.В. Сиротин А.П. "Избирательные РС усилители", М. Энергия, 1980, стр. 69) восьмиканального десятиразрядного аналого-цифрового преобразователя (АЦП) с последовательным интерфейсом max 192 серии (см. Каталог MAXIM 1993), процессора PC-104 с кварцевым генератором (см. Каталог Консорциума Advantage real time device AMPRO, 1993 стр. 103-184) и восьмиканального тринадцатиразрядного цифроаналогового преобразователя (ЦАП) с последовательным интерфейсом max 540 серии (см. Каталог MAXIM 1993). Выходные сигналы ЦАП являются выходами блока управления 1, по трем из которых, кроме сигналов запуска импульсов генерации, поступают сигналы, определяющую величину энергии накопительных конденсаторов блока питания 2 (см. Волков И. В. "Источники питания лазеров", техника, Киев, 1976, стр.118).

В качестве лазеров используются лазеры: Nd:YAG (длина волны 1,06 мкм или 1,32 мкм), Ho:YAG (длина волны 2,09 мкм) и Er:YAG (длина волны 2,94 мкм). В качестве дисперсионного элемента 28 стеклянная призма, в качестве фотодетекторов 29 кремниевые полупроводниковые фотодиоды ФД-256, а в качестве фотоэлектрического приемника инфракрасного излучения 31 германиевый фотодиод ФД-9. Элемент сравнения 30 микросхема K554CA3 или LM-111. Акустический приемник 34 микрофон В K4138.

Таким образом, предлагаемые устройства за счет совокупности заявляемых признаков, обеспечивая оперативное управление с возможностью варьирования в широком диапазоне параметрами лазерного излучения, позволяют проводить хирургические процедуры на биотканях в качестве либо скальпеля, либо коагулятора, либо деструктора в зависимости от требуемых типов, режимов и сочетаний работы лазеров, ориентированных на минимальную травматичность при данном виде воздействия на данную биоткань.

### Формула изобретения:

1. Устройство для лазерной обработки биологической ткани, содержащее блок управления, выходы которого соединены с блоком питания лазеров, импульсные лазеры, оптические оси которых параллельны, оптически сопряженные отражательное и селективно отражательное для длины волны первого лазера и прозрачное для длины волны второго лазера зеркала, которые расположены на оптических осях первого и второго лазеров, соответственно установленные на оптической оси второго лазера фокусирующую систему и оптическое волокно с наконечником, выход которого

является оптическим выходом устройства, отличающееся тем, что в него введен хотя бы один приемник информации о состоянии биологической ткани, вход которого выполнен для сопряжения с местом воздействия на ткань, а выход соединен с входом блока управления, выходы которого соединены с входами электронных ключей, установленных в цепях соединения каждого лазера с блоком питания, кроме того, отражательное зеркало установлено с возможностью вывода его из хода излучения, а на оптической оси первого лазера последовательно по ходу излучения расположена фокусирующая система и оптическое волокно с наконечником, выход которого является другим оптическим выходом устройства.

2. Устройство для лазерной обработки биологической ткани, содержащее блок управления, выходы которого соединены с блоком питания лазеров, импульсные лазеры, оптические оси которых параллельны, оптически сопряженные отражательное и селективно отражательное для длины волны первого лазера и прозрачные для длины волны второго лазера зеркала, которые расположены на оптических осях первого и второго лазеров, соответственно установленные на оптической оси второго лазера, фокусирующую систему и оптическое волокно с наконечником, выход которого является оптическим выходом устройства, отличающееся тем, что в него введен третий импульсный лазер, оптическая ось которого параллельна оптическим осям двух других лазеров, а на его оси установлено отражательное зеркало, причем отражательные зеркала установлены с возможностью вывода их из хода излучений, а на оптической оси второго лазера за селективным зеркалом установлено второе селективно отражательное для длины волны третьего лазера и прозрачное для длин волн первого и второго лазеров зеркало, оптически сопряженное с отражательным зеркалом, установленным на оптической оси третьего лазера, фокусирующей системой и входом оптического волокна, расположенных на оси второго лазера, кроме того, на каждой из осей первого и третьего лазеров последовательно по ходу излучения расположены фокусирующая система и оптическое волокно с наконечником, выходы которых являются другими оптическими выходами устройства, снабженного также

хотя бы одним приемником информации о состоянии биологической ткани, вход которого выполнен для сопряжения с местом воздействия на ткань, а выход соединен с входом блока управления, выходы которого соединены с выходом электронных ключей, установленных в цепях соединения каждого лазера с блоком питания.

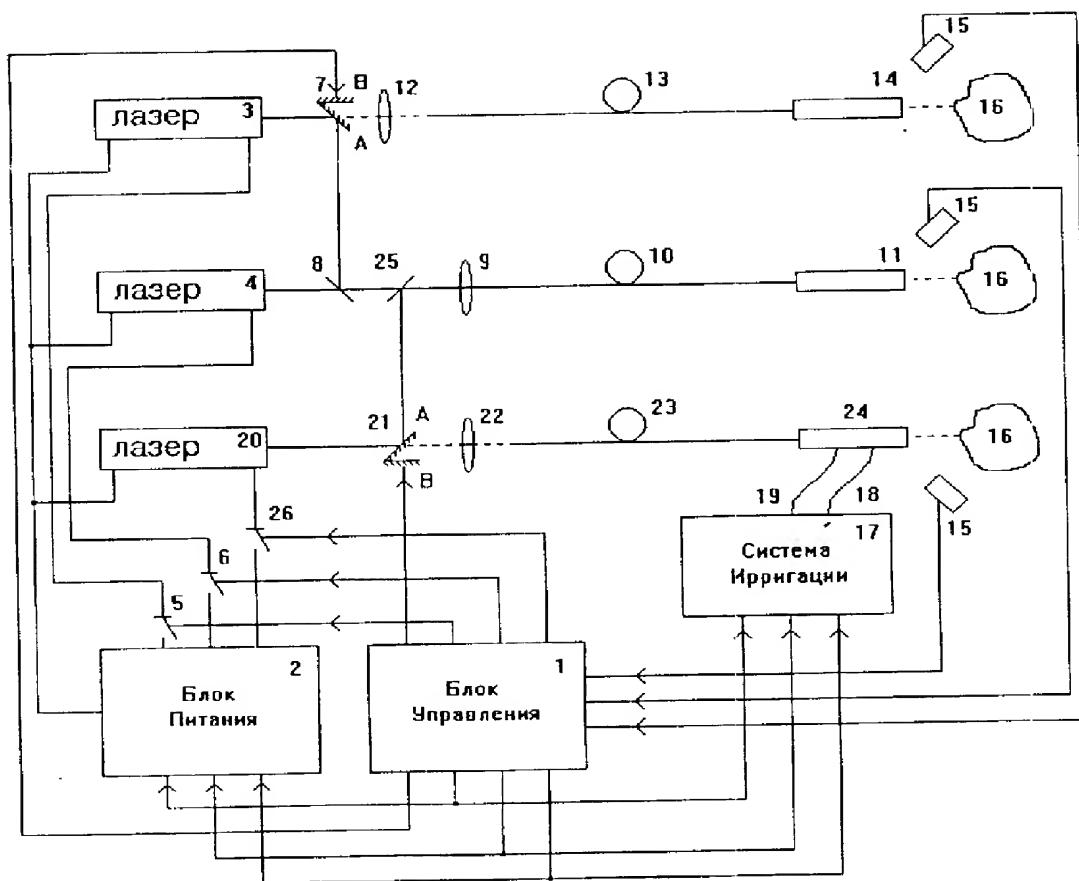
3. Устройство по пп.1 и 2, отличающееся тем, что приемник информации о состоянии биологической ткани выполнен в виде спектроанализатора в области 200 1500 нм, вход которого выполнен для оптического сопряжения с местом воздействия на ткань, и состоящего из дисперсионного элемента, линейки фотодетекторов и элемента сравнения.

4. Устройство по пп.1 и 2, отличающееся тем, что приемник информации о состоянии биологической ткани выполнен в виде фотоэлектрического приемника инфракрасного излучения, вход которого выполнен для оптического сопряжения с местом воздействия на ткань посредством поворотного зеркала, расположенного на оптической оси лазера между выходным зеркалом лазера и фокусирующей системой, через фильтр с полосой пропускания, исключающей попадание на приемник излучения лазера.

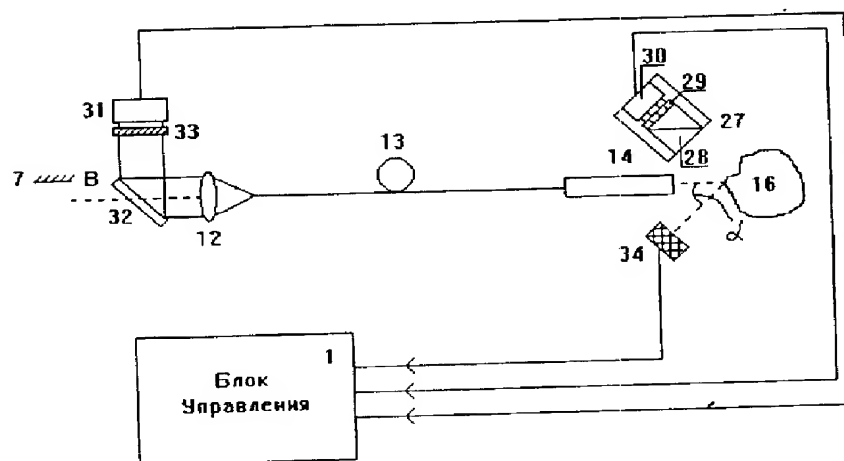
5. Устройство по пп.1 и 2, отличающееся тем, что приемник информации о состоянии биологической ткани выполнен в виде акустического приемника, установленного таким образом, что направление его максимальной чувствительности составляет с направлением оптической оси на выходе наконечника угол  $\alpha$ , удовлетворяющий условию  $11^\circ < \alpha < 86^\circ$

6. Устройство по пп.1 и 2, отличающееся тем, что электронный ключ выполнен в виде полупроводникового или электровакуумного переключателя.

7. Устройство по пп.1 и 2, отличающееся тем, что оно дополнительно снабжено системой орошения зоны обработки, состоящей из резервуара для воды с водяным насосом и воздушного компрессора, соответствующие выходы которых объединены в наконечниках и являются ирригационными выходами устройства, а воздушный компрессор в месте соединения с воздухопроводами снабжен электромагнитными клапанами, подключенными к выходам блока управления.

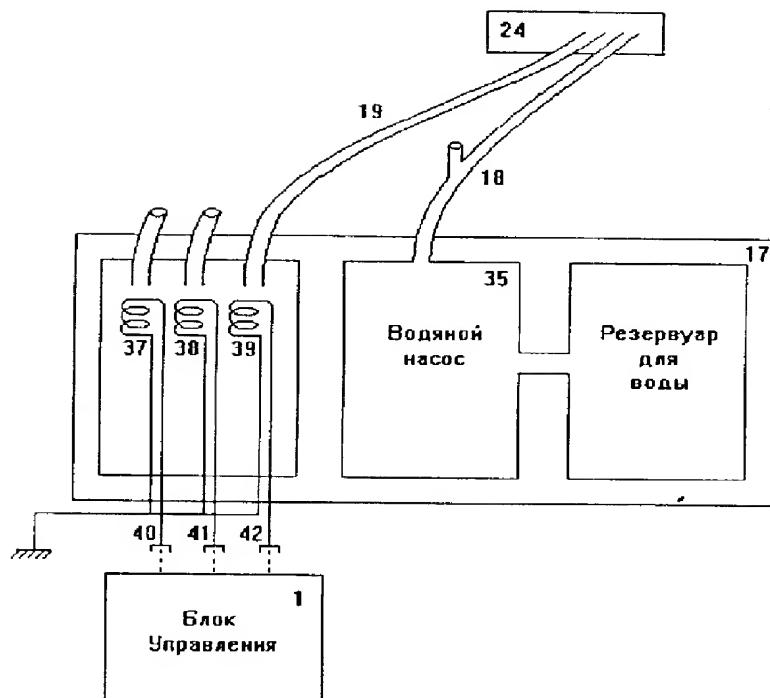


Фиг. 2

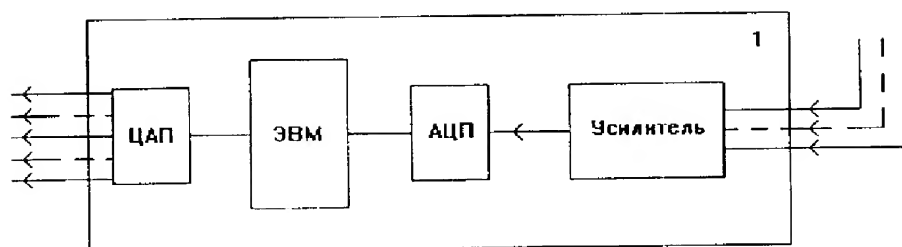


Фиг. 3





Фиг. 4



Фиг. 5

**REFLEXOTHERAPY DEVICE****Publication number:** RU2122848 (C1)**Publication date:** 1998-12-10**Inventor(s):** AL TSHULER G B; VESELOVSKIY A B; MITROFANOV A S; FEFILOV G D;  
FRAJBERG V S**Applicant(s):** UCHEBNO N PROIZV LAZERNYJ TS S; ANKT PETERBURGSKOGO INST TOCHN**Classification:**- **international:** **A61H39/06; A61H39/00;** (IPC1-7): A61H39/06- **European:****Application number:** SU19914954402 19910624**Priority number(s):** SU19914954402 19910624Abstract of **RU 2122848 (C1)**

FIELD: medical engineering. SUBSTANCE: reflexotherapy device consists of operating element secured on patient's body. Operating element includes optical-range radiation source connected electrically to power supply and control unit. Reflexotherapy device contains N operating elements. Each of them is provided with small-size convex lens made of light filtering material with cavity which accommodates radiation source. To raise efficiency of using the light energy generated by radiation source, reflecting coating is applied to lens surface nonadjacent to patient's body. To enhance treatment efficiency, radiation source is made retunable as to radiation frequency. EFFECT: enhanced efficiency. 3 cl, 2 dwge

.....  
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(19) **RU** <sup>(11)</sup> **2 122 848** <sup>(13)</sup> **C1**  
(51) МПК<sup>6</sup> **A 61 H 39/06**

РОССИЙСКОЕ АГЕНТСТВО  
ПО ПАТЕНТАМ И ТОВАРНЫМ ЗНАКАМ

## (12) ОПИСАНИЕ ИЗОБРЕТЕНИЯ К ПАТЕНТУ РОССИЙСКОЙ ФЕДЕРАЦИИ

(21), (22) Заявка: 4954402/14, 24.06.1991

(46) Дата публикации: 10.12.1998

(56) Ссылки: 1. Авторское свидетельство СССР N 1602528, А 61 Н 39/08, 1987. 2. Авторское свидетельство СССР N 1553126, А 61 Н 39/06, 1988. 3. Заявка Японии N 63-34745, кл. А 61 Н 39/00, 1988.

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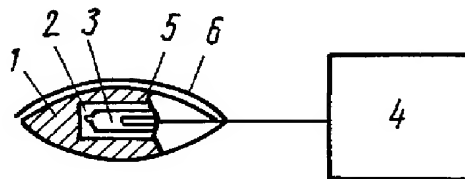
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механики и оптики

### (54) УСТРОЙСТВО ДЛЯ РЕФЛЕКСОТЕРАПИИ

(57) Реферат:

Изобретение относится к области медицинской техники и может быть использовано для проведения профилактических и лечебных процедур в кабинете рефлексотерапии. Цель изобретения - повышение эффективности лечения за счет одновременного облучения биологически активных точек излучением различного спектрального состава и увеличения глубины проникновения излучения в тело пациента без увеличения мощности источника излучения. Поставленная цель достигается тем, что в устройстве для рефлексотерапии, состоящее из закрепленного на теле пациента рабочего элемента, содержащего источник излучения оптического диапазона, электрически соединенного с блоком питания и управления, включено N рабочих элементов, каждый из которых снабжен выпуклой малогабаритной

линзой из светофильтрующего материала с полостью, в которой расположен источник излучения. Для повышения эффективности использования световой энергии, вырабатываемой источником излучения, на поверхность линзы не прилегающую к телу пациента, нанесено отражающее покрытие. Для дополнительного повышения эффективности лечения источник излучения выполнен перестраиваемым по частоте излучения. 2 з.п. ф-лы, 2 ил.



Фиг.1



(19) **RU** <sup>(11)</sup> **2 122 848** <sup>(13)</sup> **C1**  
(51) Int. Cl. <sup>6</sup> **A 61 H 39/06**

RUSSIAN AGENCY  
FOR PATENTS AND TRADEMARKS

(12) **ABSTRACT OF INVENTION**

(21), (22) Application: 4954402/14, 24.06.1991

(46) Date of publication: 10.12.1998

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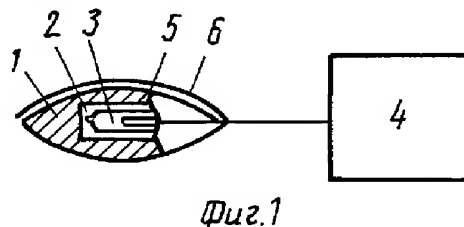
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(54) **REFLEXOTHERAPY DEVICE**

(57) Abstract:

FIELD: medical engineering. SUBSTANCE: reflexotherapy device consists of operating element secured on patient's body. Operating element includes optical-range radiation source connected electrically to power supply and control unit. Reflexotherapy device contains N operating elements. Each of them is provided with small-size convex lens made of light filtering material with cavity which accommodates radiation source. To raise efficiency of using the light energy generated by radiation source, reflecting coating is applied to lens surface nonadjacent to patient's body. To

enhance treatment efficiency, radiation source is made retunable as to radiation frequency. EFFECT: enhanced efficiency. 3 cl, 2 dwg



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Изобретение относится к области медицинской техники и предназначено для проведения профилактических и лечебных процедур посредством воздействия на биологически активные точки и зоны излучением оптического диапазона.

Известно оптическое устройство для дозированного воздействия на точки акупунктуры солнечным светом (а.с. N 1602528, кл. А 61 Н 39/08 от 02.06.87). Устройство содержит концентратор, датчик мощности излучения, жалюзи или блок поглощающих фильтров, силовой световод, блок разводящих световодов, торцы которых закрепляются в области биологически активных точек. Для облучения глубоко залегающих биологически активных точек используются инъекционные иглы с проложенными по центральному каналу световодом.

Недостатком этого устройства является:

- воздействие на точки акупунктуры только белым светом,
- невозможность воздействия одновременно на несколько точек светом различных длин волн, (различного цвета),
- большие потери световой энергии, передаваемой по световоду от концентратора к облучаемой точке,
- при использовании инъекционных игл появляется возможность инфицирования пациента, а также неприятные ощущения при введении игл,
- требуется высокая квалификация врача, вводящего инъекционные иглы на большую глубину.

Известно оптическое устройство для рефлексотерапии (а.с. N 1553126, кл. А 61 Н 39/06, от 26.06.88). В этом устройстве для воздействия лазерным излучением на биологически активные точки используется аппликатор, обеспечивающий комплексное воздействие несколькими регулируемыми параметрами на рефлексогенные зоны. Устройство содержит эластичное основание с элементами крепления. На основании установлены съемные инъекционные оптически прозрачные иглы и нагревательные элементы.

Недостатком этого устройства является:

- использование излучения только одной длины волны (цвета),
- невозможность воздействия одновременно на несколько точек акупунктуры светом различных длин волн (различных цветов),
- возможность инфицирования пациента и неприятные ощущения при введении игл,
- низкая точность попадания излучения в биологически активную точку,
- потери световой энергии, передаваемой от лазера к оптически прозрачным иглам.

В качестве прототипа выбирается устройство для лазерной терапии (заявка N 63-34745, (Япония), кл. А 61 Н 39/00, опубл. 12.07.88. Устройство включает в себя полупроводниковый лазер (инфракрасного диапазона), закрепляемый на металлическом основании, которое соединено с резиновым баллоном. В металлическом основании имеется канал для всасывания воздуха. К основанию со стороны лазерного диода прикрепляется сменный конус, позволяющий устанавливать требуемое расстояние между облучаемым органом и полупроводниковым

лазером.

В прототипе рабочая часть устройства представляет собой металлическое основание, в котором закреплен полупроводниковый лазер; отделенное от поверхности кожного покрова человека сменным корпусом, позволяющим устанавливать требуемое расстояние между облучаемым органом и лазером. Крепление рабочей части осуществляется за счет разряжения воздуха внутри конуса, что обеспечивается резиновым баллоном, закрепленным сверху металлического основания и канала в основании для всасывания воздуха.

Использование в качестве источника излучения полупроводникового лазера не позволяет изменять цвет облачающего излучения, не позволяет облучать несколько биологически активных точек излучением различного спектрального состава. Форма рабочей части устройства не позволяет производить уплотнение биологической ткани в месте входа излучения в тело пациента и повышать за счет этого глубину проникновения излучения, т.к. основание с закрепленным на нем лазером удалено от поверхности кожного покрова на расстояние, определяемое высотой конуса.

Цель изобретения - повышение эффективности лечения за счет облучения одновременно биологически активных точек или зон излучением различного спектрального состава и увеличения глубины проникновения излучения в тело пациента без увеличения мощности источника излучения.

Поставленная цель достигается тем, что в устройстве для рефлексотерапии, включающем в себя закрепляемые на теле пациента рабочие элементы, содержащих источник излучения, электрически соединенный с блоком питания и управления, каждый рабочий элемент снабжен выпуклой малогабаритной линзой из светопропускающего материала с полостью, в которой расположен источник излучения. Для повышения эффективности использования световой энергии, вырабатываемой источником излучения, на поверхности линзы, не прилегающей к телу пациента нанесено отражающее покрытие. Дополнительно повысить эффективность лечения позволяет использование перестраиваемого по частоте излучения источника излучения.

Авторами не обнаружено использование предложенного технического решения задачи в рефлексотерапии для повышения эффективности лечения, следовательно, предложенное устройство для рефлексотерапии соответствует критерию "существенные отличия".

Из (медицинской) практики рефлексотерапии известно, что лечебный эффект достигается при воздействии на биологически активную точку иглоукалыванием, механическим давлением (акуперссура, массаж), теплом или холодом, электрическим током, излучением оптического диапазона (светом) различного спектрального состава.

При лечении методом иглоукалывания, в зависимости от заболевания и в процессе лечения, одновременному воздействию подлежат несколько биологически активных точек (до двенадцати), что повышает

эффективность лечения по сравнению с воздействием на одну точку. При этом используется как возбуждающее (стимулирующее), так и угнетающее (тормозящее) воздействие на биологически активные точки, что достигается применением игл, изготовленных из различных металлов (платины, золота, серебра и т.д.) различной толщины и длины.

Использование иглотерапии сопровождается рядом негативных факторов, к которым можно отнести:

- нарушение кожного покрова и как следствие, возможность инфицирования,
- разрушение биологических тканей при многократном введении игл и одних и тех же точек,
- неприятные ощущения,
- трудность точного попадания в биологически активную точку,
- использование дорогостоящих игл (желательно индивидуальные),
- требуется высокая квалификация врача, проводящего иглоукалывание.

Круг пациентов, прибегающих к этому эффективному методу лечения в настоящее время сужается из-за возможности инфицирования различными вирусами, что стимулирует поиск альтернативных методов и устройств воздействия на биологически активные точки (модификации классической акупунктуры).

Одним из таких методов является фоторефлексотерапия, основанная на воздействии излучения оптического диапазона, как в отдельности, так и в сочетании с другими методами воздействия на биологически активные точки (акупрессура, термopунктура, точечный и линейный массаж и т.д.). Излучение оптического диапазона различного спектрального состава оказывает различное воздействие на облучаемую биологически активную точку. Синий и зеленый свет оказывает угнетающее (тормозящее) воздействие, а красный свет у возбуждающее (стимулирующее). Каждое из этих воздействий, как в отдельности, так и совокупности позволяют достигнуть лечебного эффекта (Крюк А.С. Мостовников В.А., Хохлов И.В. Терапевтическая эффективность низкоинтенсивного лазерного излучения, Минск, Наука и техника, 1986. IX.)

Выбор спектрального диапазона, воздействующего излучения может быть основан на одном из следующих принципов,

- в зависимости от особенностей физиологического воздействия того или иного цвета,
- в соответствии с тестом Люшера,
- в соответствии с традиционными представлениями восточной медицины,
- в зависимости от глубины проникновения излучения.

Биологически активные точки находятся на некоторой глубине от поверхности кожного покрова. Глубина их залегания доходит до нескольких сантиметров (8-7 см).

Глубина проникновения излучения в биологические точки зависит от длины волны излучения и с ее увеличением в видимом диапазоне возрастает. Наибольшей проникающей способностью в оптическом диапазоне обладает инфракрасное излучение с длиной волны 1 мкм и излучение красного цвета видимого диапазона (Приезжев А.В.,

Тучин В.В., Шубочкин Л.П. Лазерная диагностика в биологии и медицине: М: Наука, 1989). При уплотнении биологической ткани глубина проникновения излучения значительно возрастает (Аскарьян Г.А. Возможность усиления проникновения излучения через мутные среды, М, Препринт, 1982, N 59).

В заявляемом устройстве конструкция рабочей части устройства состоит из сменных рабочих элементов, закрепляемых на теле пациента. Каждый рабочий элемент представляет собой или содержит в себе малогабаритную выпуклую линзу из светофильтрующего материала с полостью, в которой размещен источник излучения. Рабочие элементы, обеспечивающие фиксацию источников излучения и максимум излучения в направлении биологически активной точки или зоны в месте закрепления рабочего элемента, закрепляются с помощью лейкопластыря в зонах кожных проекций выбранных точек или зон.

Такая конструкция рабочей части устройства позволяет повысить эффективность лечения за счет одновременного воздействия на несколько биологически активных точек или зон излучением требуемого спектрального состава, как одного какого-либо цвета, так и различными комбинациями цветов.

Выпуклая форма поверхности рабочего элемента, прилегающего к телу пациента, обеспечивает даже при небольшом давлении в направлении облучаемой точки акупунктуры (это достигается при фиксации рабочего элемента лейкопластырем, пояском "с липучкой" и нажатием на рабочий элемент) уплотнение биологической ткани в месте входа излучения. Это позволяет увеличить глубину проникновения низкоэнергетического излучения в тело пациента и увеличить поток излучения на биологически активную точку без увеличения мощности источника излучения, а также оказывать воздействие на глубоко залегающие биологически активные точки, до которых в обычных условиях и при использовании известных фототерапевтических устройств, излучение практически не доходило, что особенно важно при воздействии на биологически активные точки излучением синего и зеленого света, которое обладает невысокой проникающей способностью.

Использование источников излучения перестраиваемых по частоте излучения (по цвету) дополнительно повышает эффективность лечения рефлексотерапевтического устройства. При этом воздействии на биологически активные точки излучением определенного цвета осуществляется не за счет сменных малогабаритных линз из светофильтрующего материала, а путем подачи на перестраиваемый по частоте излучения источник излучения соответствующего электрического сигнала управления.

На фиг.1 изображен предлагаемый рабочий элемент рефлексотерапевтического устройства, содержащий выпуклую линзу 1, выполненную из светофильтрующего материала, внутри линзы имеется полость 2, в которой расположен источник излучения 3, электрически соединенный с блоком 4 питания и управления. На поверхности 5

линзы 1, не прилегающую при установке к телу пациента нанесено отражающее покрытие 6. При использовании малогабаритных линз для удобства их крепления линза 1 может закрепляться в оправе 7, как показано на фиг.2.

Устройство для рефлексотерапии работает следующим образом.

Согласно рекомендациям врача выбирают биологически активные точки или зоны на теле пациента, на которые необходимо оказать воздействие, порядок воздействия и метод воздействия. Выбирают цвет излучения, воздействующего на каждую выбранную точку или зону. Устанавливают соответствующие рабочие элементы 1 на выбранные биологически активные точки или зоны. На пульте блока 4 управления и питания устанавливают уровень интенсивности излучения воздействующего на точку или зону, интервал времени воздействия, режим работы источников излучения 3 (непрерывный, импульсный-синфазный, импульсный-противофазный, бегущей волны и т.д.)

После установки на пульте блока 4 управления и питания необходимого режима работы излучателей подается команда начала работы. Процесс облучения биологически активных точек или зон и их последовательность осуществляется автоматически. Порядок включения источников 3 излучения определяется программируемым коммутатором, программа работы которого устанавливается на пульте блока 4 управления.

После окончания заданной программы работы источников 3 излучения формирователь интервала времени вырабатывает сигнал, обеспечивающий отключение питания от источников 3 излучения. Затем рабочие элементы 1 снимают с кожного покрова, после чего процедура может быть осуществлена на других участках тела.

В качестве источников излучения в предложенных рабочих элементах может быть использована, например, сверхминиатюрная лампа накаливания СМН-6-80-2. В качестве перестраиваемого источника излучения может служить фосфидогалиевый эпитаксиальный двухпереходной полупроводниковый кристалл. Цвет излучения такого кристалла зависит от величины электрического тока, протекающего через каждый переход кристалла, и может изменяться от зеленого до красного цвета, перекрывая таким образом почти весь видимый диапазон (за исключением синего цвета).

Светофильтрующим материалом для

линзы может служить, например, цветное органическое стекло. Материалом для оправы линзы может служить эбонит, фторопласт, органическое стекло и им подобные материалы. Отражающее покрытие на поверхности линзы может быть изготовлено методом напыления металла, например, алюминия.

Таким образом, предложенная конструкция рабочей части устройства выполняет одновременно функции:

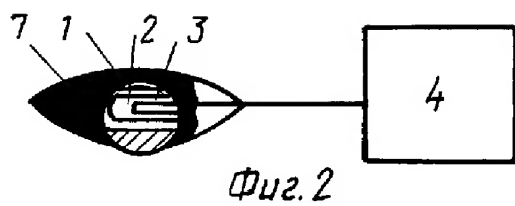
- оптического элемента, осуществляющего спектральную фильтрацию излучения (роль светофильтра) для получения излучения требуемого цвета,
- оптического элемента, осуществляющего формирование пучка излучения, позволяющего увеличить световой поток в направлении облучаемой биологически активной точки (роль собирающей линзы) а при нанесении отражающего покрытия и роль отражателя, фокусирующего излучение в направлении биологически активной точки,
- уплотнителя биологической ткани в месте закрепления рабочего элемента, что обеспечивает повышение глубины проникновения излучения и увеличения потока излучения, падающего на облучаемую точку,
- держателя источника излучения.

#### Формула изобретения:

1. Устройство для рефлексотерапии, включающее закрепляемый на теле пациента рабочий элемент, содержащий источник излучения, электрически связанный с блоком питания и управления, отличающийся тем, что, с целью повышения эффективности лечения за счет облучения одновременно биологически активных точек или зон излучением различного спектрального состава и увеличения глубины проникновения излучения в тело пациента без увеличения мощности источника излучения, оно дополнительно снабжено N рабочими элементами, каждый из которых выполнен сменным и в виде выпуклой малогабаритной линзы из светофильтрующего материала с полностью, в которой расположен источник излучения.

2. Устройство по п.1, отличающееся тем, что, с целью повышения эффективности использования световой энергии, вырабатываемой источником излучения, на поверхность линзы, не прилегающую к телу пациента, нанесено отражающее покрытие.

3. Устройство по п.1, отличающееся тем, что источник излучения выполнен перестраиваемым по частоте излучения, а светофильтрующий материал прозрачен в диапазоне частот перестройки источника излучения.



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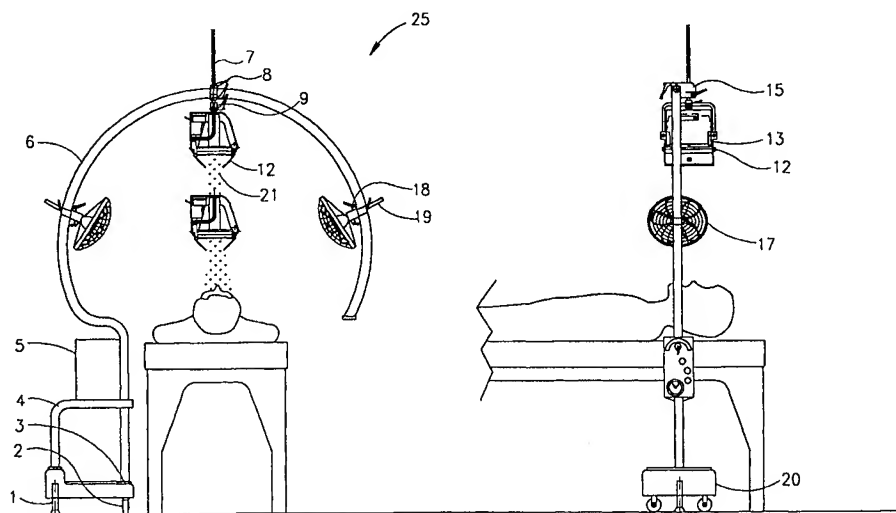
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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>A61B 17/36</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/02491</b> <b>(43) International Publication Date:</b> 20 January 2000 (20.01.00)
<b>(21) International Application Number:</b> PCT/IL99/00374 <b>(22) International Filing Date:</b> 7 July 1999 (07.07.99) <b>(30) Priority Data:</b> 60/092,225                      9 July 1998 (09.07.98)                      US <b>(71)(72) Applicants and Inventors:</b> HARTH, Yoram [IL/IL]; Nordau Street 35, 33124 Haifa (IL). KORMAN, Avner [IL/IL]; Hadar Street 55, 46326 Herzlia (IL). <b>(74) Agent:</b> EITAN, PEARL, LATZER & COHEN-ZEDEK; Gav Yam Center 2, Shenkar Street 7, 46725 Herzlia (IL).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

**(54) Title:** APPARATUS AND METHOD FOR EFFICIENT HIGH ENERGY PHOTODYNAMIC THERAPY OF ACNE VULGARIS AND SEBORRHEA

**(57) Abstract**

This invention is an apparatus, and method for the phototherapy of different skin conditions, particularly acne vulgaris, and seborrhea. The invention consists of a combined treatment with violet/blue light source (13) with a spectral emission in the range of 405 nanometer to 440 nanometer, possible additional spectral bands in the green, the red part of the spectrum, and the topical application of oxygen transporting compounds, and/or a methylene blue solution. The apparatus includes at least one narrow spectral band light source with spectral emitting concentrated in the violet/blue spectral band, and an optical system for controlling spectra, beam parameters of said light source (13), a mechanical fixture (9) for holding said light source (13) at an adjustable distance, the direction related to the skin treated area, an electronic unit (40) to control the duration, the power, and spectral bands of the emitted radiation.

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## APPARATUS AND METHOD FOR EFFICIENT HIGH ENERGY PHOTODYNAMIC THERAPY OF ACNE VULGARIS AND SEBORRHEA

### FIELD AND BACKGROUND OF THE INVENTION:

The present invention relates to an apparatus and method for the  
5 photodynamic therapy treatment of acne vulgaris and seborrhea and, more particularly, to a violet/blue light radiating system that illuminates a collimated narrow bandwidth beam on the treated skin area. The method relates to the combined photodynamic skin treatment including narrow band violet/blue light radiation and topical application of oxidative and/or keratolytic agents.

10 The enlargement and obstruction of sebaceous glands cause acne vulgaris. Due the accumulation of sebum in the glands, bacteria, mainly propionibacterium acnes (p. acnes), proliferate in the glands. These bacteria cause inflammation and later the formation of pustular lesions and acne cysts, which heal by scarring.

15 It is known that p. acnes produce porphyrins. It is also known that visible light in the violet/blue (405-410 nanometer range), or less efficiently, red (630-670 nanometer range) are able to induce a photodynamic effect in which the porphyrins in the enlarged sebaceous glands react with oxygen to form peroxides. These peroxides are short-lived toxic compounds that are able to eliminate, or  
20 considerably diminish, the number of bacteria in the glands.

Photodynamic therapy (PDT) is based on the optimal interaction of 4 elements; light, photosensitizer, oxygen and skin penetration. Prior patents and publications related to acne phototherapy dealt only with the first two elements of PDT, i.e., and light exposure and sebaceous gland porphyrins. Studies have  
25 shown that the photodestruction of p. acnes is increased exponentially in an oxygen rich environment.

Various attempts have been made to treat acne with light; Mendes et al. (US patent 5,549,660) described a method for the light therapy of acne using low intensity red light. Their apparatus was meant to treat acne through it effect on  
30 macrophages in the skin. In contrast to the present invention its low light intensity is not sufficient for an efficient photodynamic destruction of p. acnes in the deeper

layers of the skin. High intensity visible light phototherapy for acne was described by Meffert et al., (Dermatol-Monatsschr. 1990; 176(10): 597-603) but they used a light source emitting not only visible light but also UVA comprising up to 15-20% of the total irradiation dose. Sigurdsson et al (Dermatology 1997; 94:256-260). used  
5 Philips HPM-10 400W combined with an UVILEX 390- filter (Desag. Germany) that filters most but not all ultraviolet A (UVA) harmful rays. The spectrum of their lamp peaked at 420 nanometer and had 2 other small peak of emission at 405 and 435 nanometer. Their apparatus emitted at 40 cm; 0.5J/cm<sup>2</sup> of UVA, 20 Jcm<sup>2</sup>/of violet/blue and 5 J/cm<sup>2</sup> of green light.

10 There is thus, a widely recognized need for, and it would be highly advantageous, to have a way to practice the enhanced photodynamic therapeutical effect of the combined violet/blue radiation with oxidant or oxygen transporting agents skin treatment by the use of an apparatus and a method to establish these improved treatment healing effects.

15 Methylene blue is a dye used parentally for treatment of methemoglobinemia in newborns and topically for disinfecting of skin. In vitro and in vivo studies have shown that Methylene blue may be activated by light to induce a photodynamic reaction. Methylene blue was used for the inactivation of herpes virus helicoabacter pillory and for the experimental therapy of skin bladder and  
20 esophageal cancers. We claim that our method of photodynamic therapy using may also be enhanced by adding an external photosensitizing agent such as methylene blue in a concentration of 0.1-5%.

## SUMMARY OF THE INVENTION

Basic science research has shown in vitro that the viability of p. acnes relates inversely to light intensity and to oxygen levels to which the p. acnes are exposed. Sigurdsson et al achieved with their apparatus 30% reduction of the total severity of acne and particularly 49% reduction of the number of pustules. The rate of success can be drastically improved by adding and penetrating oxygen to the skin daily and / or immediately before skin exposure to high intensity violet/blue light

According to the present invention there is provided an apparatus and a method with improved selectivity and efficiency of acne phototherapy by the use of a specially designed violet/blue and possibly additional spectral line light source, combined with a pre-treatment application on the treated skin area of an oxygen transporting compounds based on the use of one or more of the materials from the group of compounds consisting of perfluorocarbons, oxidative substances, keratolytic substances and external photosensitizer such as methylene blue 0.1-5 %. The apparatus for photodynamic treatment of at least one skin disorder from the group consisting of acne and seborrhea according to the present invention, including: (a) at least one light source with spectral emittance concentrated in at least one specific narrow spectral band, wherein one spectral band is in the range of 405 to 440nm; (b) An optical system for collecting and shaping the emitted light of at least one light source; and (c) An electronic unit to control at least one of the parameters from the group consisting of the duration, power and emitted spectral bands of the light source emittance.

According to further features in the preferred embodiments of the present invention, the apparatus also includes; a mechanical fixture for holding the light source at an adjustable distance and direction related to the skin treated area.

According to further features in the preferred embodiments of the present invention the apparatus also includes; at least one of a group consisting of a liquid filled light guide and a fiber bundle lightguide, as an integral part of the optical system, for collecting and conducting the said light source radiation and illuminating the skin treated area at an adjustable distance, energy density and direction.

According to still further features in the preferred embodiments of the present invention, the apparatus at least one light source is a specially designed Gallium and Lead halides gas mixture discharge lamp with peak emission in the 405-440nm spectral band.

5        According to still further features in the preferred embodiments of the present invention, the apparatus at least one light source is an Ion Krypton gas laser with a spectral emission in the range 405 to 440nm.

      According to still further features in the preferred embodiments of the present invention, the apparatus at least one light source is at least one diode  
10       selected from the group consisting of violet/blue laser diodes and light emitting diodes (LED) with narrow spectral band emission in the range 405-440nm.

      According to still further features in the preferred embodiments of the present invention, the apparatus light source is any combination of the light sources included in the previously described embodiments.

15       According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by an elliptical cross-section cylindrical reflector.

      According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by a elliptical  
20       cross-section cylindrical reflector and further collimated by a set of two orthogonal cylindrical lenses.

      According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by a elliptical cross-section cylindrical reflector and is collected at its second focal point by a slit  
25       shape input aperture of a slit to circular beam shaping and conducting fiber bundle.

      According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by a parabolic cross-section cylindrical reflector.

      According to the present invention there is provided a method of treating  
30       acne vulgaris and seborrhea with light radiation source having spectral characteristics of at least one of a group of narrow spectral bands consisting of violet/blue (405-440nm), red (630-670) and green (520-550nm) light, combined

with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluorocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method including the steps of: (a) application of the at least one compound to the treated skin area; (b) illuminating the treated skin area with the light radiation source; and (c) at least one additional exposure after a time gap of at least 24 hours.

According to further features in the preferred embodiments of the present invention, there is provided a method of treating acne vulgaris and seborrhea with a high intensity light source, having at least one narrow band violet/blue spectral radiation, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluorocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method including the steps of: (a) illuminating the treated skin area with the light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm; (b) concentrating and directing the light on the skin by an optical system and a mechanical fixture; (c) daily and/or pretreatment application of at least one compound selected from the compound group; and (d) 1-5 weekly exposure to violet/blue light for typically 2- 10 weeks, with minimum 24 hours time gap between exposures.

According to still further features in the preferred embodiments of the present invention, there is provided a method of treating acne vulgaris and seborrhea with a high intensity light source, having at least two narrow radiation bands one violet/blue light and one red light, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluorocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method including the steps of: (a) illuminating the treated skin area with the light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm and a second wavelength band emittance of 630-670 nanometer range (red); (b) concentrating and directing the light on the skin by an optical system and a mechanical fixture; (c) daily and/or pretreatment application of at least one compound selected from the compound group; and (d) 1-5 weekly exposure to

violet/blue light for typically 2- 10 weeks, with minimum 24 hours time gap between exposures.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the radiation is concentrated and projected on the acne afflicted area with an illumination power in the range of 10mW/cm<sup>2</sup> to 500mW/cm<sup>2</sup> of violet/blue light radiation.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the concentration of hydrogen peroxide in the applied compound is 1-10% by weight and the concentration of salicylic acid is 1-10% by weight.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the at least one material selected from the group of oxidative and keratolytic compounds is applied either daily or immediately before light exposure.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the oxidative and/or keratolytic compound is within a material selected from the group consisting of a liposome and a positively-charged submicron emulsion.

According to still further features in the preferred embodiments of the present invention there is provided a method wherein the oxidative and/or keratolytic compounds is in a propylene glycol 10-50% base.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the oxidative compound is a oil in water emulsion mixed with molecular oxygen that is sprayed continuously on the skin before or during light exposure.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the methylene blue 0.1-5% in distilled water or gel base is applied to the skin before or during light exposure.

The proposed method successfully addresses the shortcomings of the presently known treatment methods and related experimental system configurations. The proposed method provides a new method to enhances in a substantial way the efficiency of the suggested photodynamic therapeutical effect,



by increasing significantly the oxygen pressure in the sebaceous glands through the use of oxygen transporting compounds based on perfluorocarbons and/ or oxidative emulsions. The proposed method also enhances light and compound penetration into the skin using translucent gels and keratolytic agents. It also  
5 provide a way to increase the photodestruction of p. acnes by providing high intensity monochromatic light exactly matching the optimal action spectrum of the photosensitizer.

In contrast to the light sources used previously by Meffert and Sigurdsson the present invention apparatus presents a major advance towards the goal of  
10 using phototherapy to effectively and safely treat acne and seborrhea. the proposed apparatus emits high intensity non-coherent light in the exact narrow spectral band needed for the activation of the photodynamic reaction filtering the harmful UV light. This narrow and specific wavelength range radiation enables the administration of sufficient intensity of light to the deeper layers of the dermis  
15 without excessive heat formation in the epidermis. The required spectral band is emitted by the present invention light source for the photodynamic destruction of p. acnes in the acne sebaceous glands.

In vitro research (Malik Z, Nitzan Y, Harth Y, Korman A. to be submitted for publication) showed that exposure to the proposed apparatus achieves a  
20 decrease in propionibacterium acnes from  $10^9$  to  $<10^4$  after two 30, 60 minutes exposures separated by 72 hours of dark incubation. (figure 6).

In vitro studies show that the destruction of p. acnes may be further enhanced by adding methylene blue 0.5% to the broth prior to irradiation.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic front and side view illustrations of one embodiment of the photodynamic treatment apparatus according to the present invention.

FIGS. 2A and 2B are schematic side view and front view illustrations respectively of the illumination head unit, the same embodiment of the present invention apparatus wherein the illumination unit head structure is based on a violet/blue light source of a gas discharge lamp;

FIGS. 3A and 3B are schematic elevational and bottom views respectively of the light source unit in the apparatus of Fig. 1, in an embodiment wherein the illumination unit structure is based on a circular array of LED's, or laser diodes, emitting a narrow spectral band red light illumination component, the array is integrated on the perimeter of a parabolic cross-section reflector, in the focal point of which is situated a high illumination intensity, narrow spectral band, violet/blue light gas discharge light source;

FIG. 4 is a schematic bottom view illustration of the present invention violet/blue light source, in another preferred embodiment, wherein the illumination unit structure is based on a two dimensional array of LED's, or laser diodes, emitting a preferred narrow spectral band violet/blue light illumination component, the two dimensional array can also include any spatial distribution combination of violet/blue narrow spectral band emitting laser diodes or LED's, together with red light LED's, or laser diodes emitting in the preferred red spectral band;

FIG. 5 illustrates a typical spectral distribution of the light energy emitted by the present invention dedicated violet/blue light source, in the embodiments wherein the light source is a gas discharge lamp;

FIG. 6A - 6C illustrate another set of an additional three preferred embodiments of the illumination head in the apparatus according to the present invention, wherein all these embodiments are based on the application of a single axis elliptical cross-section cylindrical reflector, in the first focal point of which is fitted the illuminating gas discharge lamp arc. The image of the gas discharge light source arc is created in the second focal point of the elliptical reflector and can be

then directly used for object illumination, or collected and further conducted by a fiber optic slit to circular beam shaping bundle, or collected and reshaped by a dedicated set of two orthogonal cylindrical lenses, to optimally conduct and collimate the light energy on the patient's treated skin areas; and

- 5           FIG. 7 illustrates the results of the proposed apparatus, laboratory controlled tests on p. acne, showing a decrease in propionibacterium acnes in 4-5 orders of magnitude, after two 30, or 60 minutes exposures separated by 72 hours of dark incubation.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of an apparatus, which can be used for photodynamic treatments in phototherapy. Specifically, the present invention can be used for the non-invasive treatment of acne vulgaris and seborrhea, thereby  
5 enabling treating various parts of the patient's body with ability to control the illumination power, energy spatial distribution, exposure duration and illumination source emittance spectral bands.

The principles and operation of the apparatus for phototherapy treatment according to the present invention may be better understood with reference to the  
10 drawings and the accompanying description.

Referring now to the drawings, Fig 1 is a schematic front and side view illustration of the photodynamic treatment apparatus according to the present invention, which is referred to herein below as system **25**.

System **25** includes a violet/blue light source fixture **13**, which can be  
15 moved repositioned and directed to the treated patient specific skin area by adjustment unit **15**. It can also be lifted up or lowered down in order to change the effective radiated energy flux on the treated area, by using pole unit **7** and handle **8**. The apparatus light source is mounted on a mechanical arc shaped fixture **6** for holding and supporting the light source at an adjustable distance and direction  
20 related to the patient's treated skin area. The apparatus mechanical fixture **9** allows horizontal, vertical and radial placement and directing of light beam **21** from the light unit **13** to the patient's treated part of the body.

Unit **17** is a schematic presentation of an air blower or a fan that serves to cool and remove excess heat from the treated skin area. Units **18** and **19** are  
25 mechanisms to adjust required position of unit **17**.

Unit **5** is a control board for the apparatus enabling control of lamp power, illumination duration, air cooling operational parameters and general on/off and mains control functions.

Units **4** and **20** are a structural element and a balancing weight to stabilize  
30 the apparatus in a vertical up-right position. Unit **3** is a mechanical axis around which the entire apparatus arc shaped structure **6** can be rotated and refitted in any required horizontal angular position related to the treated patient bed **22**.

Wheel **2** and pole **1** are elements required to move and refit the position of the apparatus according to the operational needs of the system operator.

Light source fixture **13** consists of a lamp or a laser light source that emits violet/blue light with a peak at 405-420nm. Close to a hundred percent of the light source ultra violet/blue light (UV) is filtered out by an integrated optical system. The required narrow spectral emission band of violet/blue light source is radiated by the present patent dedicated arc lamp due to a special gas mixture within the lamp, or by a gas laser source, or by a violet/blue light emitting semiconductor diode junction. The above light sources in a single source type embodiment, or in a combination of two or three type of light sources, allows optimal violet/blue light radiation with or without additional narrow spectral band lines in the red or green parts of the spectrum. The present invention light source enables the minimization of heat production at the treated target to a max. of 23 degrees Celsius on the epidermis at 30-40 cm. A mechanical shutter **12** in front of the light source **13** may be used to exactly define the treated area.

Figures 2A and 2B are schematic side and front view illustrations of the illumination head unit **13** according to the present invention, referred to herein below as system **28**.

Illumination system **28** includes a filter unit **121** for filtering out the radiated energy spectral part which is out of the preferred specific bandwidth in the violet/blue and/or the red spectrum, as previously described in the above background paragraph of the invention. Unit **111** is a set of four mechanical flaps with a control knob **112** and a pivoting axis **110** that create together an adjustable aperture iris unit to control the size and collimation parameters of system **28** radiated light beam. U shaped arm **114** holds and supports the illumination unit housing **113**. Unit **109** enables rotation of the system **28** around vertical pivot axis **107** and to lock it in the preferred rotational angle. Unit **115** enables changing position by sliding and further fixing in a preferred position system **28** along the apparatus support arc **106**. Unit **115** also enables sliding system **28** up or down and then fixing its position. Unit **122** is an optional mechanical support housing and a lens for focusing and concentrating the system **28** illumination beam on a smaller

area of the treated skin, thus creating a higher light energy flux whenever required for a specific treatment.

Figures 3A and 3B are schematic elevational and bottom view of another preferred embodiment of the present invention lighting head unit **13** of the apparatus described in figure 1, referred to herein below as system **30**.

System **30** includes a housing unit **31** and a reflector **32** having preferably a parabolic vertical cross section. The gas discharge lamp **33** is assembled into reflector unit **32** in a way that fixes the center of the lamp illumination arc in the focal point of the reflector. Lamp **33** is a specially designed Gallium and Lead halides gas mixture discharge lamp with peak emission in the 405-430 spectral band.

Unit **34** is a circular array of red emission LED's or red light laser diodes installed around the aperture perimeter of the reflector unit **33**.

Figure 4 is a schematic illustration of another preferred embodiment of the present invention lighting head unit **13** of the apparatus described in figure 1, referred to herein below as system **40**.

System **40** includes a housing unit **42** and a two-dimensional array of LED's, or laser diodes **41**, emitting a narrow spectral band violet/blue light illumination component. These semiconductor solid state light sources can be GaN or ZnSe components. The two-dimensional array can also include narrow spectral band red light LED's, or laser diodes, emitting in the preferred red spectral band. Unit **43** is a mechanical structure for attaching system **40** to the apparatus of figure 1.

Figure 5 illustrates a typical spectral distribution of the light energy emitted by the present invention dedicated violet/blue gas discharge lamp based light source, before further spectral optical filtration is done, in the embodiments wherein the light source is a gas discharge lamp.

Figure 6A. is a schematic cross section illustration of one of a set of three possible preferred embodiments of the present invention lighting head unit **13** of the apparatus described in figure 1, the first possible embodiment is referred to herein below as system **50**. Light source head embodiment of system **50** consists of a housing **51** that supports an arc lamp, or a line beam shape laser light source

**52** that emits violet/blue light with a peak at 405-420nm. The light source is fixed in the first focal point **54** of an elliptical cross section shape reflector **53**. The energy emitted out of the preferred spectral band reflected by the elliptical shaped reflector and is imaged as a line source at its second focal point **55**. From the secondary focal point the beam is diverging at a small angle and creates an oval shaped illumination area **81** of typical size 20X10 cm. at a convenient treatment distance of 40 cm. from the lamp housing exit aperture. The non violet spectral part of the light source emission is rejected and filtered out by filter unit **56** and the lamp housing is sealed by tempered glass window **57** possibly coated with a heat mirror layer for the protection of the patient against heat and explosion. The required narrow spectral emission band of violet/blue light source is radiated by the present invention dedicated arc lamp due to a special gas mixture within the lamp, or by a violet/blue light emitting semiconductor diode junction array. The above light sources in a single source type embodiment, or in a combination of two or three type of different spectral emission bands light sources alternative embodiment, allows optimal violet/blue light radiation with, or without additional narrow spectral band lines in the red or green parts of the spectrum.

Figure 6B. is a schematic cross section illustration of a second possible preferred embodiment of the present invention lighting head unit **13** of the apparatus described in figure 1, the second possible embodiment is referred to herein below as system **60**. Light source head embodiment of system **60** consists of a housing **61** that supports an arc lamp, or a line beam shape laser light source **62** that emits violet/blue light with a peak at 405-420nm. The light source is fixed in the first focal point **64** of an elliptical cross section shape reflector **63**. The energy emitted out of the preferred spectral band reflected by the elliptical shaped reflector and is imaged as a line source at its second focal point **65**. In the secondary focal point the beam is entering a slit shape fiber bundle aperture, matching the size and shape of the imaged light line at this point. **68**. At the exit circular aperture **67** of this fiber bundle the emerging light is diverging at a typical 40 degrees angle and creates a circular shaped illumination area while its size and consequently the illumination power density can be controlled by changing the distance from the exit fiber end **67** to the patient treated skin area. The non violet spectral part of the

light source emission is rejected and filtered out by filter unit **66** and the lamp housing is sealed by a cover window **69**. The above light sources in a single source type embodiment, or in a combination of two or three type of different spectral emission bands light sources alternative embodiment, allows optimal violet/blue light radiation with, or without additional narrow spectral band lines in the red or green parts of the spectrum.

Figure 6C. is a schematic cross section illustration of a third possible preferred embodiment of the present invention lighting head unit **13** of the apparatus described in figure 1, the third possible embodiment is referred to herein below as system **70**. Light source head embodiment of system **70** consists of a housing **71** that supports an arc lamp, or a line beam shape laser light source **72** that emits violet/blue light with a peak at 405-420nm. The light source is fixed in the first focal point **74** of an elliptical cross section shape reflector **73**. The energy emitted out of the preferred spectral band reflected by the elliptical shaped reflector and is imaged as a line source at its second focal point **75**. After passing through in the secondary focal point **75** the beam is entering a set of two cylindrical lenses **76** and **77**, which are orthogonal oriented in respect of their linear axis. At the exit of this lens system aperture **78** a close to a circular light illumination area is created of typical size 20X20 cm. at a convenient treatment distance of 40 cm. from the lamp housing exit aperture. The non violet spectral part of the light source emission is rejected and filtered out by filter unit **79** and the lamp housing is sealed by a cover window **80**. The above light sources in a single source type embodiment, or in a combination of two or three type of different spectral emission bands light sources alternative embodiment, allows optimal violet/blue light radiation with, or without additional narrow spectral band lines in the red or green parts of the spectrum.

FIG. 7 illustrates the results of the proposed apparatus laboratory controlled tests on p. acne showing a decrease in propionibacterium acnes  $10^9$  to  $<10^4$  after two 30 and 60 minutes exposures separated by 72 hours of dark incubation.

The method according to the present invention improves the present art treatment methods in a major way by adding oxygen transporting compounds



based on perfluorocarbons and/or oxidative and /or keratolytic agent, daily and or immediately pretreatment. The proposed oxygen transporting agents i.e., perfluorocarbons lipophilic emulsion, release nascent oxygen directly into the sebaceous glands achieving a 76% O<sub>2</sub> environment as compared to the atmospheric 20%. The proposed oxidative agents i.e., emulsion or gel of H<sub>2</sub>O<sub>2</sub> 1-10%, release by contact with the enzyme cathalase present in the skin nascent oxygen. The specific formulations of the emulsion or gel prevent the upward release of the oxygen and cause a short temporary inward pressure of up to 15 Atm. of O<sub>2</sub>, penetrating to the sebaceous situated in the deeper layers of the skin.

10        The oxygenation of the skin during the phototherapy process raises the efficiency of the desired photodestruction of p. acnes and thus decreases of acne lesion number and severity. Added keratolytic agent (i.e. 1-5% salicylic acid) to the applied formulation will enhance diffusion of O<sub>2</sub> into the sebaceous glands. Cooling of the applied emulsion or gel minimizes the heat in the epidermis thus allowing a  
15 further increase of the light intensity in the sebaceous glands.

It is to be understood that the invention is not limited in its applications to the details of construction or drawings. The invention is capable of other embodiments, or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed above is for the  
20 purpose of description and should not be regarded as limiting. While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

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## CLAIMS

1. An apparatus for photodynamic treatment of at least one skin disorder from the group consisting of acne and seborrhea, comprising:
  - (a) at least one light source with spectral emittance concentrated in  
5 at least one specific narrow spectral band, wherein one spectral band is in the range of 405 to 440nm;
  - (b) An optical system for collecting and shaping the emitted light of said at least one light source; and
  - (c) An electronic unit to control at least one of the parameters from  
10 the group consisting of the duration, power and emitted spectral bands of said light source emittance.
2. The apparatus of claim 1. further comprising:
  - a mechanical fixture for holding said light source at an adjustable distance and direction related to the skin treated area.
- 15 3. The apparatus of claim 1. further comprising:
  - at least one of a group consisting of a liquid filled light guide and a fiber bundle lightguide, as an integral part of said optical system, for collecting and conducting said light source radiation and illuminating the skin treated area at an adjustable distance, energy density and  
20 direction.
4. The apparatus of claim 1, wherein said at least one light source is a specially designed Gallium and Lead halides gas mixture discharge lamp with peak emission in the 405-440 spectral band.
5. The apparatus of claim 1, wherein said at least one light source is an Ion  
25 Krypton gas laser with a spectral emission in the range 405 to 440nm.
6. The apparatus of claim 1, wherein said light source is at least one diode selected from the group consisting of violet/blue laser diodes and light emitting diodes (LED) with narrow spectral band emission in the range 405-440nm.

7. The apparatus of claim 1, wherein said light source is any combination of the light sources included in claims 4, 5 and 6.
8. The apparatus of claim 1, wherein the light of said at least one light source is collected by an elliptical cross-section cylindrical reflector.
- 5 9. The apparatus of claim 1, wherein the light of said at least one light source is collected by a parabolic cross-section cylindrical reflector.
- 10 10. The apparatus of claim 8, wherein the light of said at least one light source is collected and further collimated by a set of two orthogonal cylindrical lenses.
- 10 11. The apparatus of claim 8, wherein the light of said at least one light source is collected at its second focal point by a slit shape input aperture of a slit to circular beam shaping and conducting fiber bundle.
12. A method of treating acne vulgaris and seborrhea with light radiation source having spectral characteristics of at least one of a group of narrow spectral bands consisting of violet/blue (405-440nm), red (630-670) and green (520-550nm) light, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluorocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method comprising the steps of:
  - 15 application of said at least one compound to the treated skin area;  
Illuminating the treated skin area with said light radiation source;  
and  
at least one additional exposure after a time gap of at least 24 hours.
- 25 13. A method of treating acne vulgaris and seborrhea with a high intensity light source, having at least one narrow band violet/blue spectral radiation, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluorocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method comprising the steps of:
  - 30

illuminating the treated skin area with said light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm;

concentrating and directing the light on the skin by an optical system and a mechanical fixture;

daily and/or pretreatment application of at least one compound selected from said compound group; and

1-5 weekly exposure to violet/blue light for typically 2- 10 weeks, with minimum 24 hour's time gap between exposures.

- 10 14. A method of treating acne vulgaris and seborrhea with a high intensity light source, having at least two narrow radiation bands one violet/blue light and one red light, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluoroocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method comprising the steps of:

illuminating the treated skin area with said light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm and a second wavelength band emittance of 630-670 nanometer range (red);

concentrating and directing the light on the skin by an optical system and a mechanical fixture;

daily and/or pretreatment application of at least one compound selected from said compound group; and

1-5 weekly exposure to violet/blue light for typically 2- 10 weeks, with minimum 24 hours time gap between exposures.

15. A method of treating acne vulgaris and seborrhea with in accordance to claim 12, wherein the radiation is concentrated and projected on the acne afflicted area with an illumination power in the range of 10mW/cm<sup>2</sup> to 500mW/cm<sup>2</sup> of violet/blue light radiation.

16. The method according to claim 12, wherein the concentration of hydrogen peroxide in the applied compound is 1-10% by weight and the concentration of salicylic acid is 1-10% by weight.
17. The method according to claim 12, wherein at least one material selected  
5 from the group of oxidative and keratolytic compounds is applied daily.
18. The method according to claim 12, wherein the material selected from the group of oxidative and keratolytic compounds is applied immediately before light exposure.
19. The method according to claim 12, wherein the material selected from the  
10 group consisting of oxidative and keratolytic compounds is cooled.
20. The method according to claim 12, wherein the material selected from the group consisting of oxidative and keratolytic compounds is in an aqueous gel.
21. The method according to claim 12, wherein the material selected from the  
15 group consisting of oxidative and keratolytic compounds is in oil in water emulsion.
22. The method according to claim 12, wherein the oxidative and/or keratolytic compound is within a material selected from the group consisting of a liposome and a positively charged submicron emulsion.
23. The method according to claim 12, wherein the oxidative and/or keratolytic  
20 compounds is in a Propylene glycol 10-50% base.
24. The method according to claim 12, wherein the oxidative compound is a oil in water emulsion mixed with molecular oxygen that is sprayed continuously on the skin before or during light exposure.
25. The method according to claim 12, wherein methylene blue 0.1-5% in  
25 distilled water or gel bases is applied to the skin before or during light exposure.

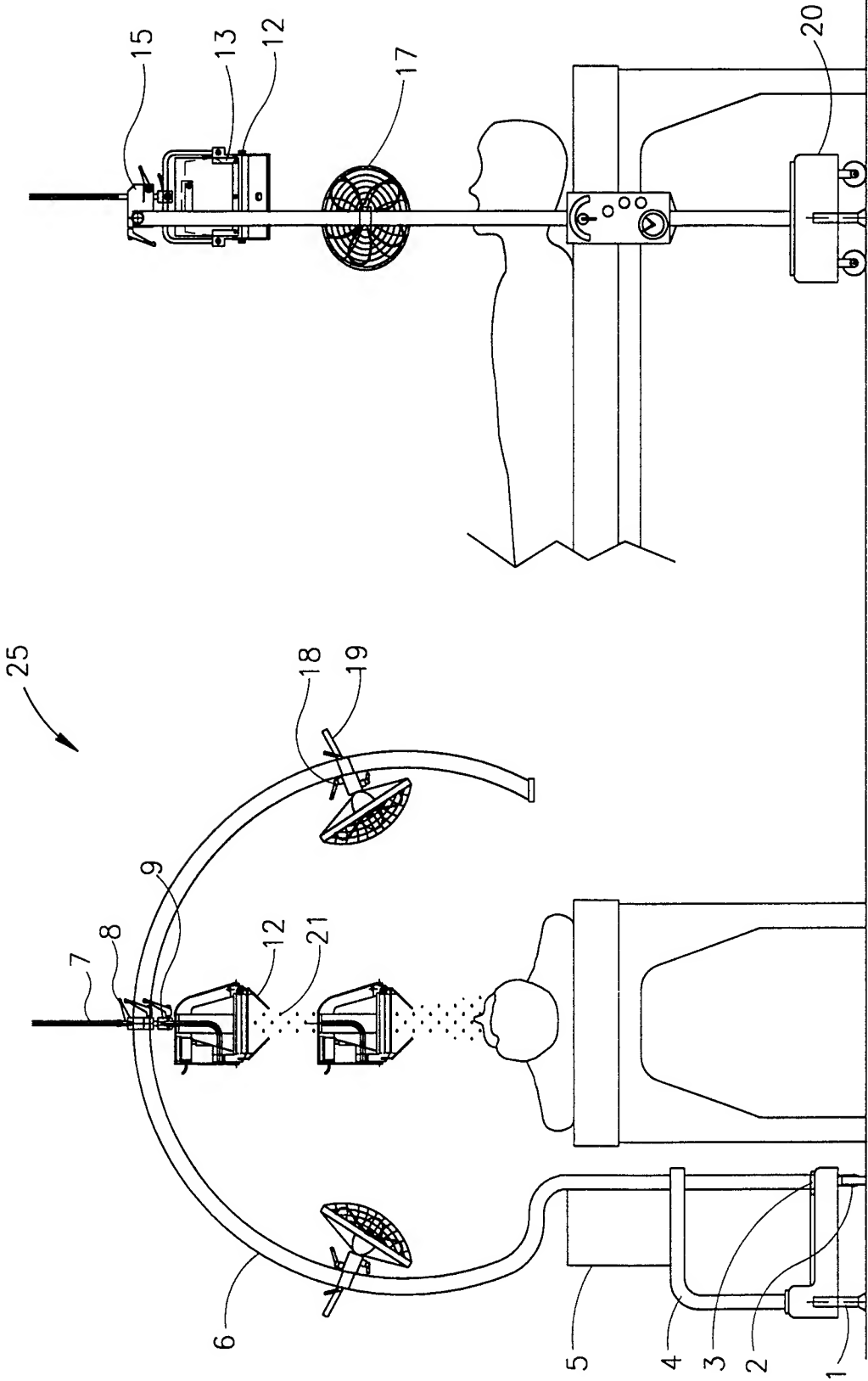


FIG.1

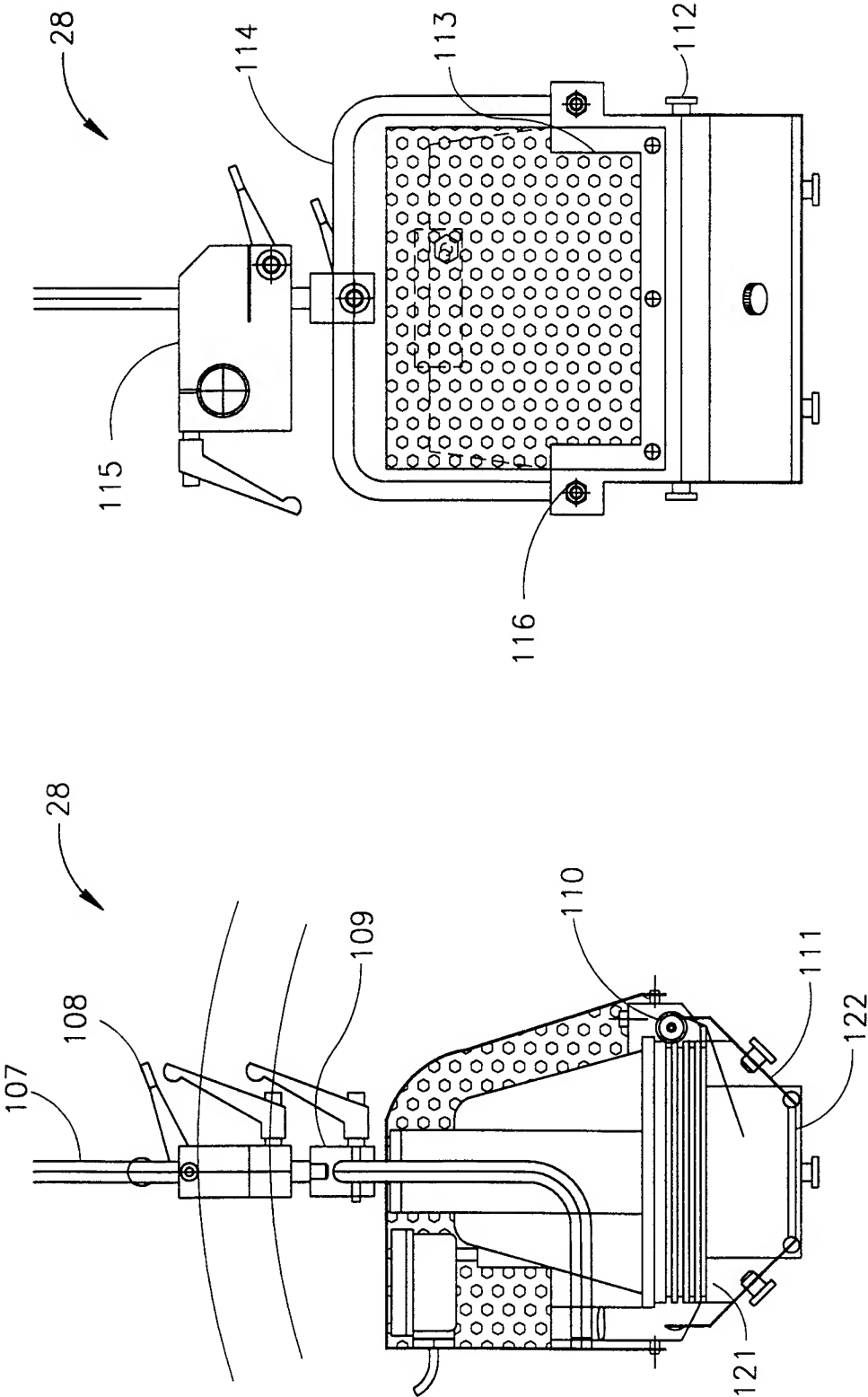


FIG.2B

FIG.2A

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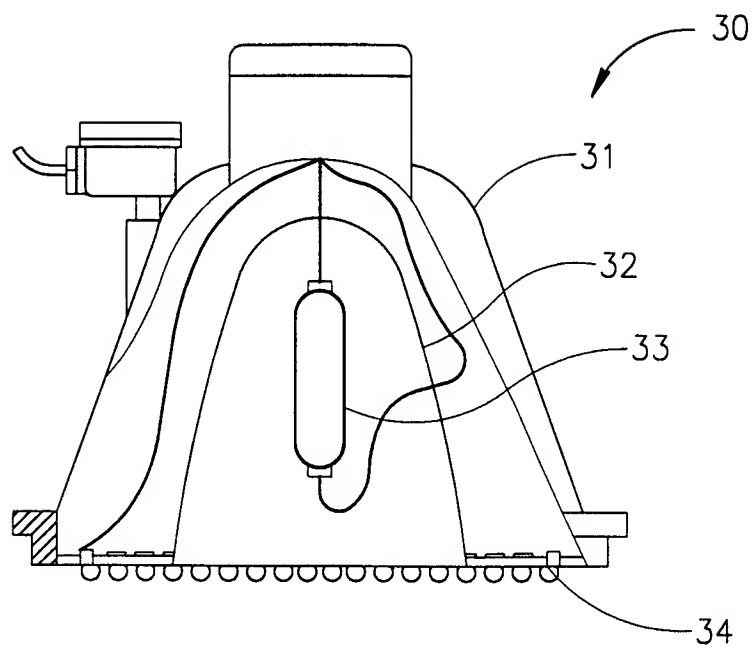


FIG. 3A

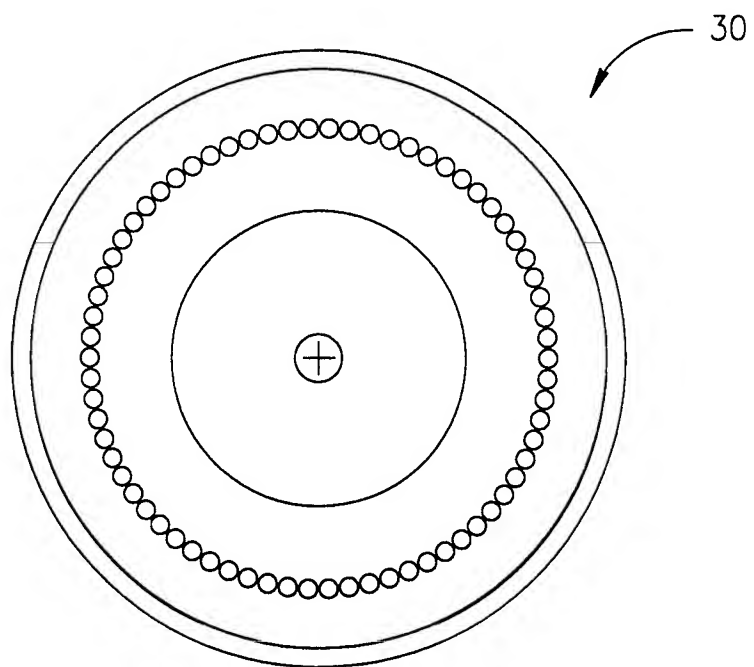


FIG. 3B



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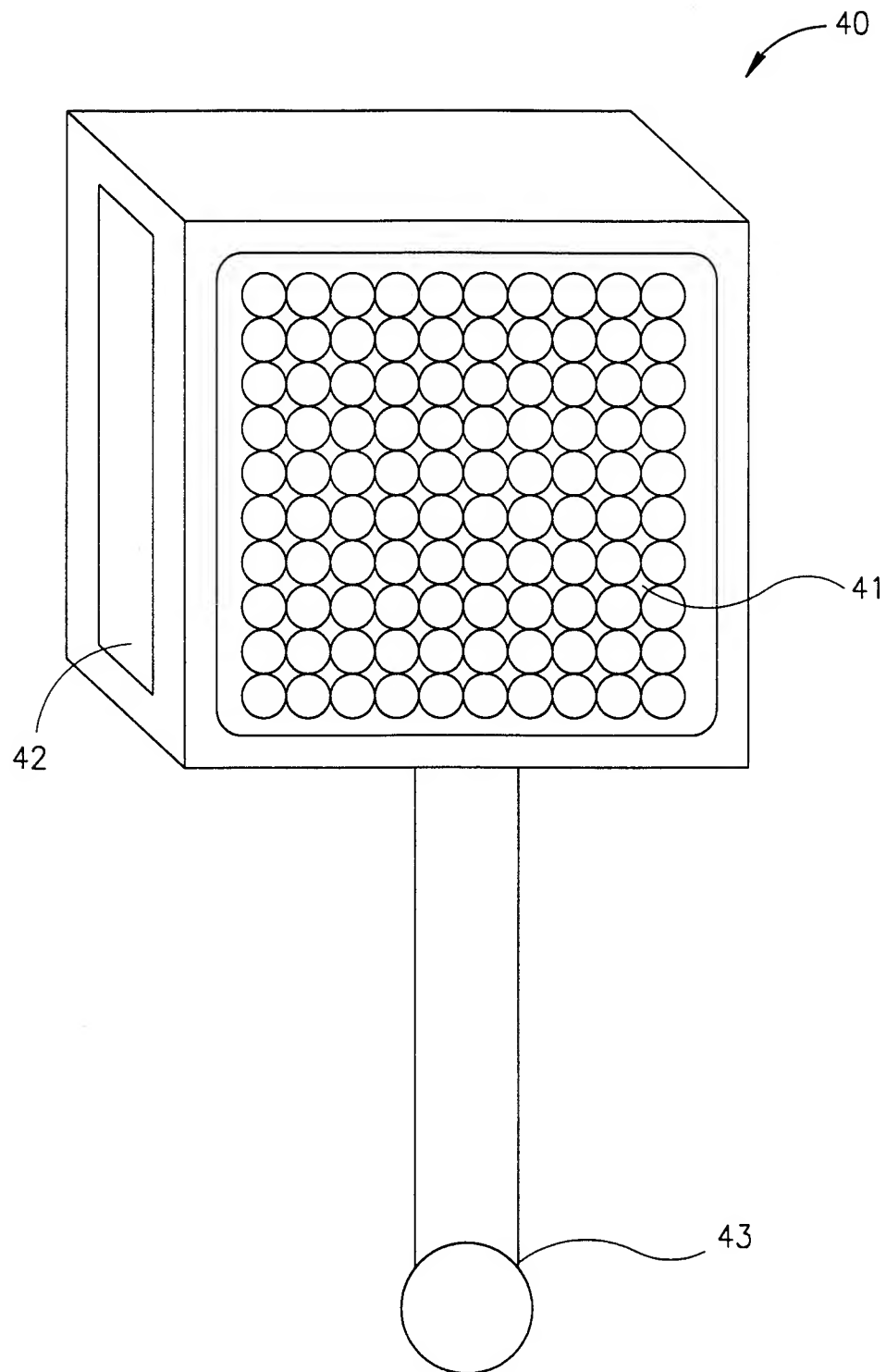


FIG. 4

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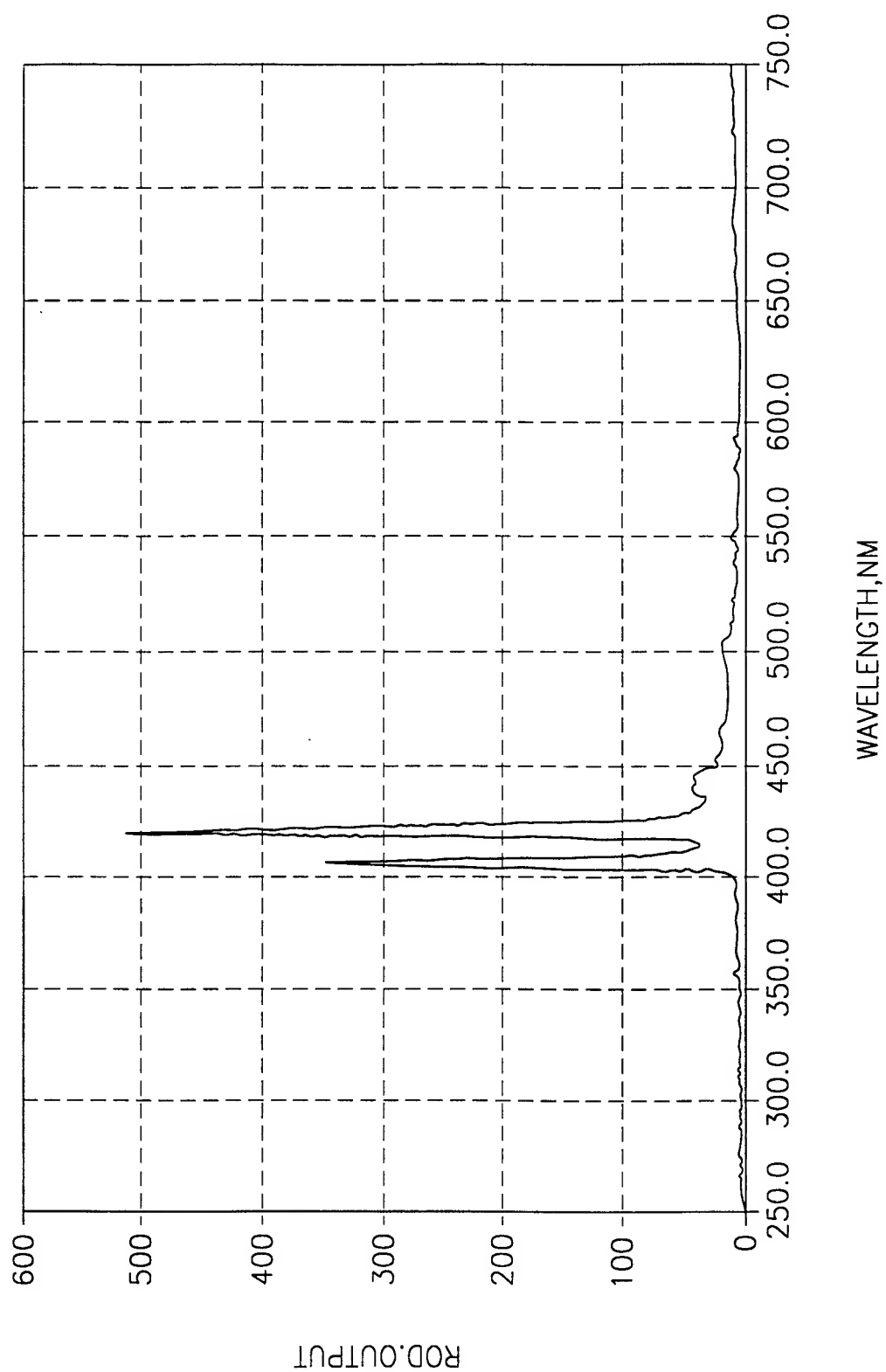


FIG.5

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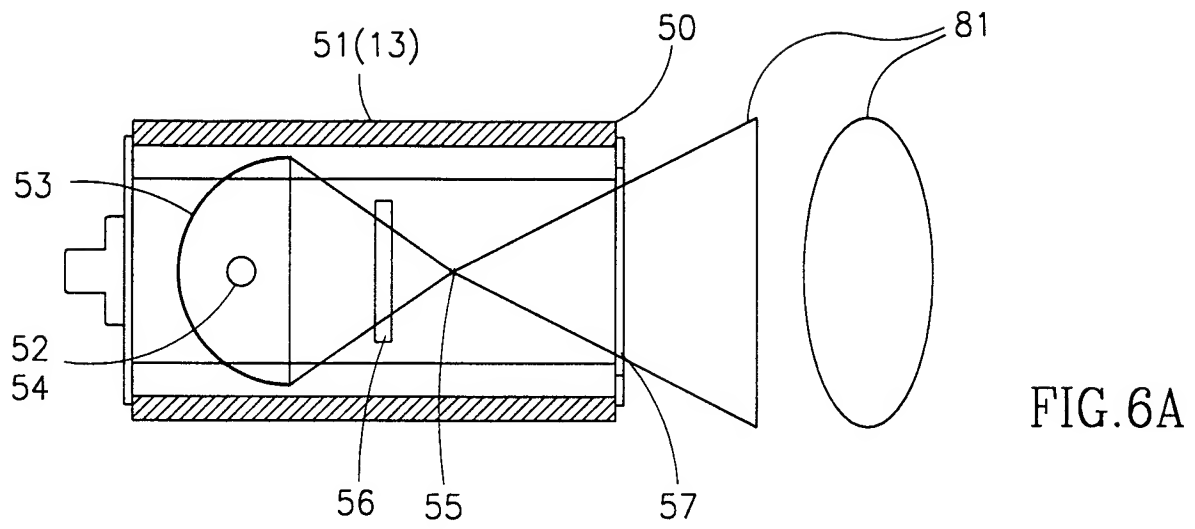


FIG. 6A

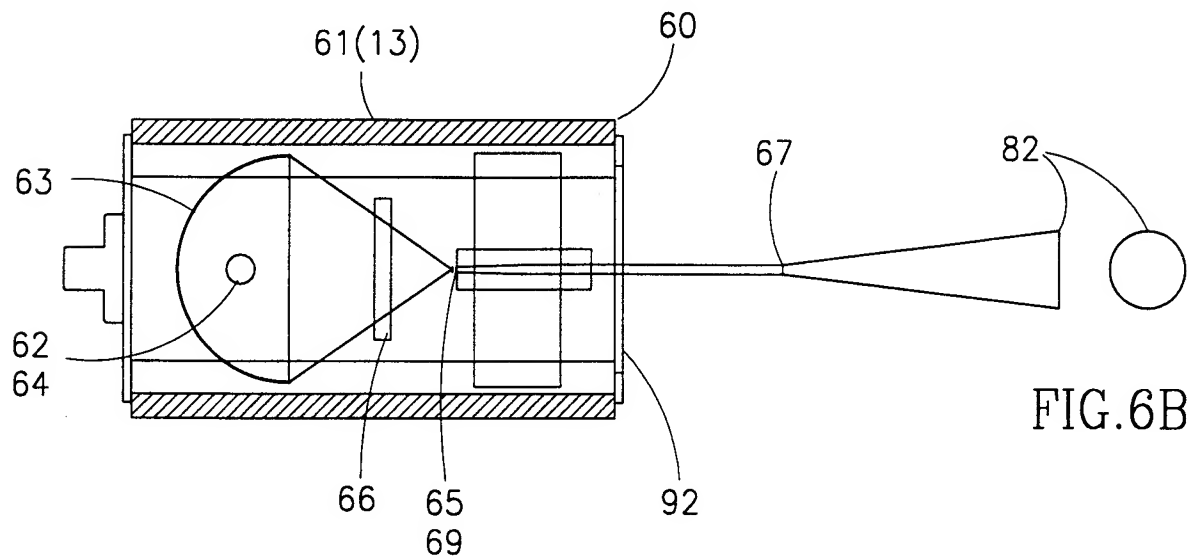


FIG. 6B

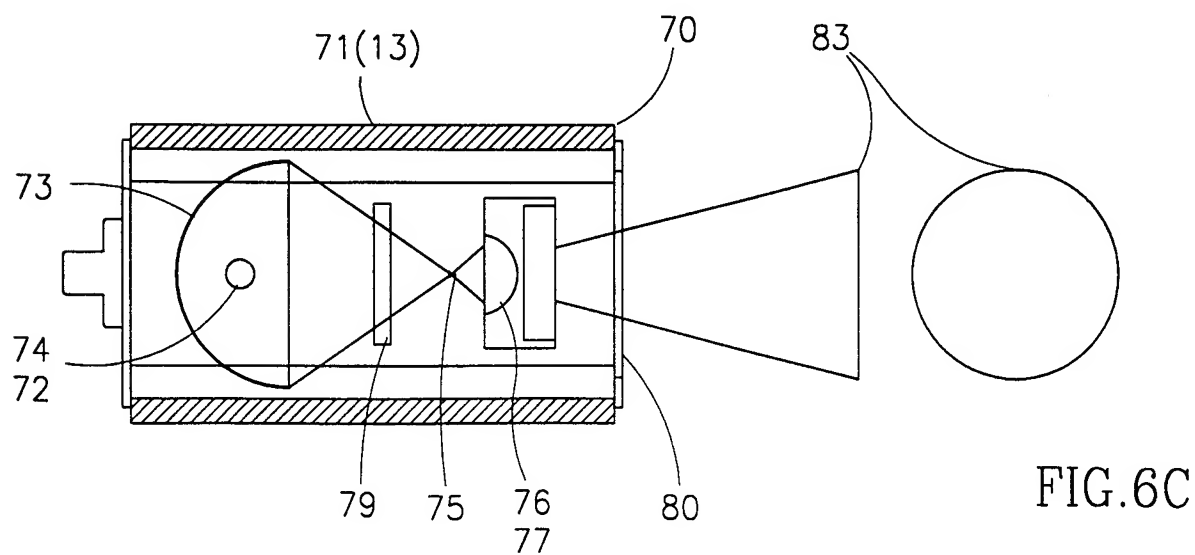


FIG. 6C

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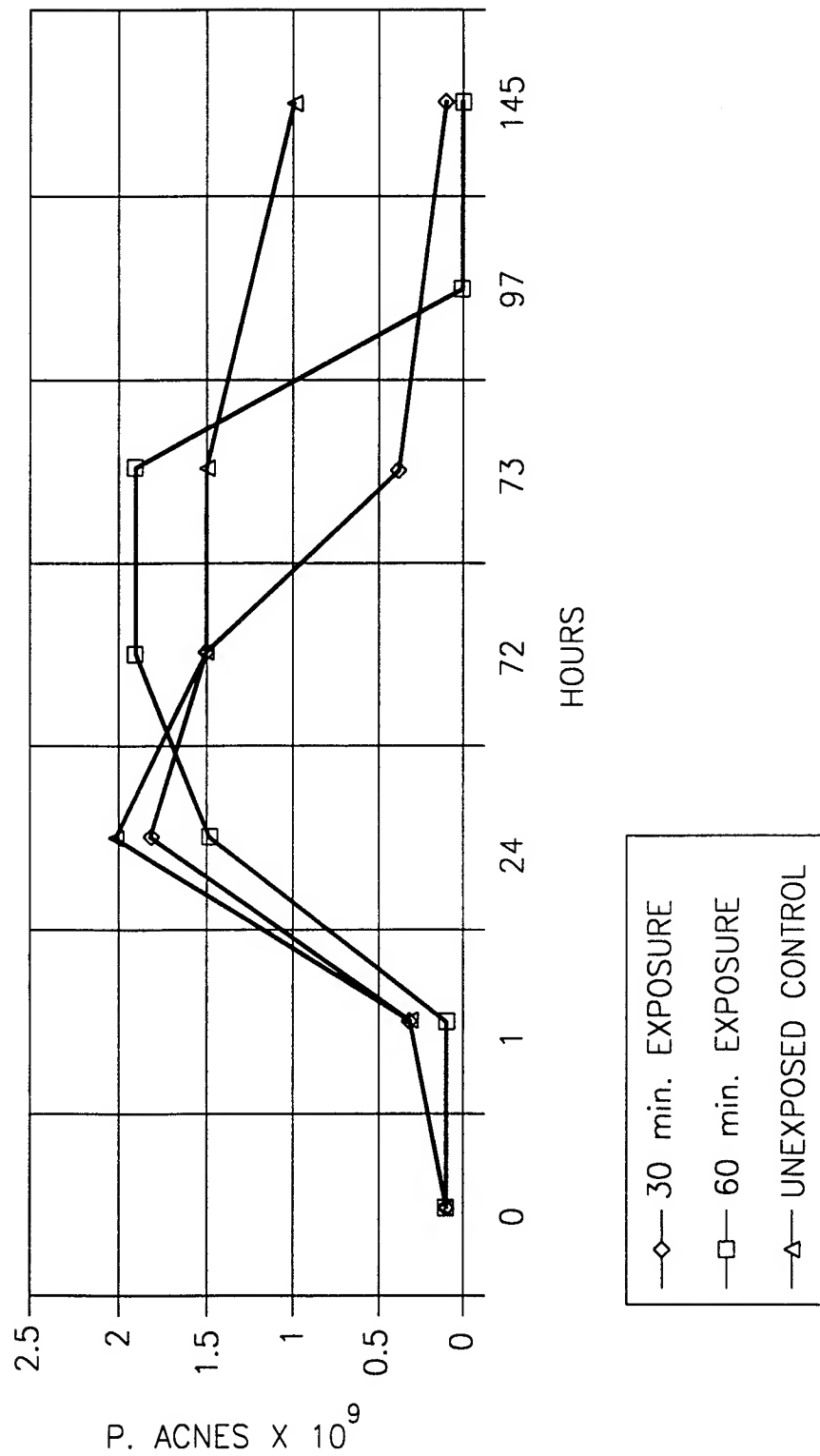


FIG.7

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL99/00374

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :A61B 17/36

US CL :606/009; 607/88

According to International Patent Classification (IPC) or to both national classification and IPC

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U.S. : 606/1, 3, 9, 16, 17, 19; 607/88-90

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	US 5,817,089 A (TANKOVICH et al.) 06 October 1998, see entire document.	1-25
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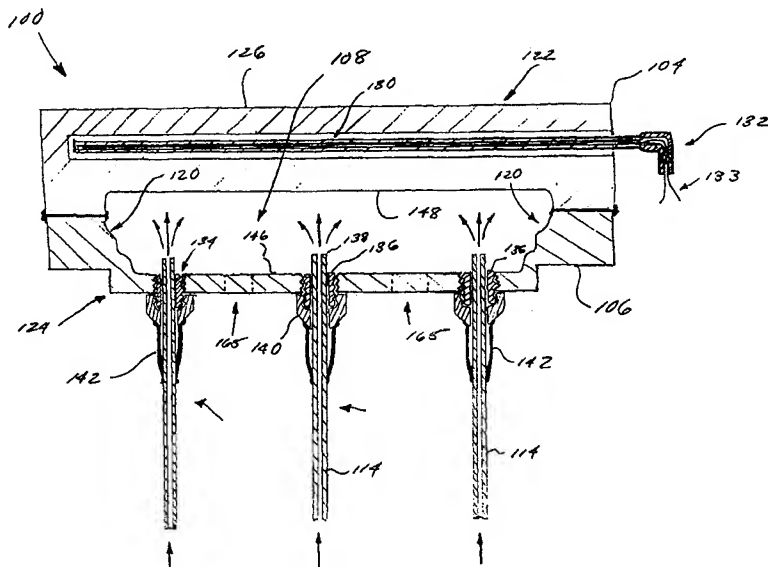
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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b>  <b>G01R 31/28</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/03257</b>  <b>(43) International Publication Date:</b> 20 January 2000 (20.01.00)
<b>(21) International Application Number:</b> PCT/US99/15609 <b>(22) International Filing Date:</b> 12 July 1999 (12.07.99)  <b>(30) Priority Data:</b> 09/114,691                      13 July 1998 (13.07.98)                      US  <b>(71) Applicant:</b> SIGMA SYSTEMS CORPORATION [US/US]; 3163 Adams Avenue, San Diego, CA 92116 (US).  <b>(72) Inventor:</b> STEWART, Robert, T.; 4728 Larueda Drive, La Mesa, CA 91941 (US).  <b>(74) Agent:</b> ALTMAN, Daniel, E.; Knobbe, Martens, Olson & Bear, LLP, Sixteenth Floor, 620 Newport Center Drive, Newport Beach, CA 92660-8016 (US).		<b>(81) Designated States:</b> AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the</i> <i>claims and to be republished in the event of the receipt of</i> <i>amendments.</i>

**(54) Title:** THERMAL PLATFORM AND METHOD**(57) Abstract**

A thermal platform for testing and/or conditioning components, having a sealed housing with internal cavity, a plurality of coolant distribution penetrations leading to the cavity, and a plurality of heater elements. A series of identical high pressure coolant lines evenly distribute coolant from a central supply manifold to respective penetrations, the latter forming an array within the bottom of the thermal platform housing. Uniform coolant distribution is further accomplished via nozzles located at the ends of the high pressure lines such that the coolant flowing out of the nozzles impinges directly on the bottom side of the platform top surface. Liquid/gaseous phase coolant is returned to the coolant supply via a series of low-pressure return ports. Precise temperature control of the platform is further maintained through the selective use of the heating elements which are located immediately adjacent to the top surface.

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## THERMAL PLATFORM AND METHOD

Background of the Invention**I. Field of the Invention**

The present invention relates generally to temperature control devices, and more particularly to precision thermal platforms used for testing and/or conditioning electronic or other components.

**II. Description of the Related Technology**

Thermal platforms are well known in the component testing and conditioning field. Such platforms are designed to accomplish a variety of testing and conditioning functions, including generally 1) maintaining a uniform temperature (either above or below ambient) of a component for a given period of time; and 2) ramping the temperature of a component up or down at a given rate, often to comparatively extreme temperatures. Such platforms are especially well adapted to conditioning components with flat thermally conductive surfaces (such as silicon wafers or semiconductor die).

Since manufacturer's ratings for such components are in part derived from thermal testing and conditioning, it is essential that the test equipment (in this case the thermal platform) accurately create and maintain the desired temperature profile during testing/conditioning across the entire component or population of components. For example, great economies of scale can be realized by testing or conditioning an entire 8 inch (200 mm) silicon wafer having many distinct die across its width at one time, as opposed to addressing each die individually. However, such economies can only be realized where the thermal platform can maintain sufficient temperature control (e.g., minimal variation) across the entire wafer. A temperature gradient of even a few degrees could potentially result in "overconditioning" or even thermally induced failure of certain die, depending on where and how the temperature is measured. Alternatively, incomplete conditioning or exposure may result for other die. During testing, electrical measurements of the components taken under such circumstances may be inaccurate or not representative of the true performance of the device at the target temperature or rate of temperature change.

Existing prior art thermal platforms have attempted to maintain a desired temperature (or rate of temperature change) with a high degree of accuracy through the combined use of electrical heating elements and cryogenic (or mechanical) refrigeration. However, as shown in the exemplary configuration of Figure 1, such prior art systems have been unable to achieve a highly uniform temperature (e.g., low temperature gradient) across the platform surface due to uneven heating and cooling of this surface. This uneven heating and cooling stems largely from the uneven distribution of coolant (liquid nitrogen, carbon dioxide, or other refrigerant) with respect to the platform test surface. Specifically, as shown in Figure 1, a small number of comparatively large coolant distribution lines have been used, with little consideration as to their placement in relation to the test surface. Furthermore, such lines provide a high coolant flow rate (required to provide the cooling needs of the entire platform/surface area), thereby causing significant temperature gradients throughout the platform due to uneven coolant distribution and thermal lag (e.g., lag time in transferring heat from a remote portion of the platform to a colder region local to a coolant distribution line). The coolant flow rate from such lines is uneven, since the lines are of different lengths, tortuosity, and diameter, thereby resulting in different flow resistances (head loss). Additionally, such prior art distribution lines do not provide for direct impingement or spray of the coolant onto the bottom



of the test surface which helps minimize undesired latency (thermal lag and temperature excursions) and significant spatial temperature gradients.

Based on the foregoing, an improved thermal platform is needed which maintains a high degree of thermal control, e.g., both minimal variation around the desired or target temperature, and controllability during temperature  
5 ramping, as well as a minimum temperature gradient across the platform test surface. Such a platform would ideally be of sufficient size and construction to permit the testing or conditioning of a broad array of components.

#### Summary of the Invention

The present invention satisfies the aforementioned needs by providing an improved thermal platform having a novel coolant distribution and retrieval system and method of operating the same.

10 In a first aspect of the invention, a thermal platform having a specially shaped internal cavity and plurality of coolant distribution penetrations is disclosed. A series of identical high pressure coolant lines distribute the coolant from a central supply manifold to respective ones of the aforementioned penetrations, the latter forming an array within the bottom of the thermal platform housing so as to distribute coolant evenly to the entire top surface of the platform. Uniform coolant distribution is further accomplished via the ends of the high-pressure lines, which form nozzles within the  
15 cavity such that the coolant flowing out of the lines impinges directly on the bottom side of the platform top surface. Liquid/gaseous phase coolant is returned to the coolant supply via a series of low-pressure return ports also located in the bottom of the thermal platform housing. Precise temperature control of the top surface is further maintained through the use of a plurality of heating elements which are immediately adjacent to the top surface.

In another aspect of the invention, a method of maintaining a highly uniform temperature across the top surface  
20 of the aforementioned thermal plate is disclosed. Coolant is injected into the cavity of the platform using the array of high-pressure distribution lines at a rate determined by a temperature controller, while one or more of the heating elements are energized in order to maintain the platform temperature (or rate of temperature increase/decrease) constant.

#### Brief Description of the Drawings

Figure 1 is a perspective view of a prior art thermal platform.

25 Figure 2a is an exploded bottom perspective view of a first embodiment of the thermal platform of the present invention, showing the upper and lower housing elements, plurality of coolant distribution and return lines, and heater elements.

Figure 2b is a detail perspective view of a high pressure distribution line nozzle fitting installed on the thermal platform of Figure 2a.

30 Figure 2c is a bottom plan view of the array of coolant distribution and return penetration in the bottom plate of the thermal platform of Figure 2a.

Figure 3 is a cross-sectional view of the thermal platform of Figure 2a (fully assembled) taken along line 3-3.

Figure 4 is a cross-sectional view of the coolant distribution manifold of the thermal platform of Figure 2a.

Figure 5a is bottom perspective view of a second embodiment of the thermal platform of the present invention  
35 having a cylindrical housing.

Figure 5b is plan view of the bottom plate of the thermal platform of Figure 5a showing the relative location of the coolant distribution and return penetrations.

Figure 5c is a plan view of the top surface of the thermal platform of Figure 5a, showing the relative locations of the radial heater element recesses.

5 Figure 6a is a bottom perspective view of a third embodiment of the thermal platform of the present invention.

Figure 6b is a plan view of the top surface of the thermal platform of Figure 6a, showing the relative location and angle of the coolant nozzles.

#### Detailed Description of the Preferred Embodiments

Reference is now made to the drawings wherein like numerals refer to like parts throughout.

#### 10 *Description of Thermal Platform Apparatus*

A first embodiment of the thermal platform of the present invention is shown in Figure 2a. The thermal platform 100 is comprised in part of a housing 102 which consists of two housing elements, e.g., upper housing element 104, which has a flat upper surface (not shown), and lower housing element 106, which has a flat lower surface. These elements 104, 106 are mated together (as described further below) to form a sealed interior cavity 108. Although square in cross-  
15 section in the present embodiment, it can be appreciated that the shape and size of the housing 102 (including, inter alia, the depth of the cavity 108 and the number of individual housing elements 104, 106) may be varied depending on the particular application. See, for example, the discussion of Figures 5a-5c and 6 below. A plurality of penetrations 134 are provided in array fashion (Figure 2b) in the bottom surface 112 of the lower housing element 106 to permit the insertion of high pressure coolant distribution lines 114 therein. The coolant lines 114 are of equal length, diameter, and construction  
20 so as to provide essentially identical coolant flow to the various penetrations 134. The lines 114 are further connected to a common distribution manifold 116 which ports high pressure coolant from a coolant source (not shown) to each of the distribution lines 114. Each of the cooling lines 114 is mated to the lower housing element 106 via a threaded compression fitting 136, 140 (Figure 2c) or any suitable joint which permits leak-tight coolant flow. Note that while the present embodiment utilizes a total of twelve (12) high pressure lines 114 and associated penetrations, any number of lines and  
25 penetrations which accomplish the desired level of temperature uniformity and control within the platform 100 may be used.

Referring now to Figure 3, the embodiment of Figure 2 is described in additional detail. The upper and lower housing elements 104, 106 are comprised of walls 120 which bound the cavity 108 on its sides, as well as an upper (top) plate 122 and lower (bottom) plate 124 which bound the cavity from above and below, respectively. The cavity shape and  
30 dimensions are preferably chosen so as to provide a suitable cavity volume (and refrigerant mass) as well as the most efficient and uniform heat transfer from the top plate 122 to the coolant. In the present embodiment, the cavity cross-sectional shape matches that of the top plate (e.g., square) for this reason. The top plate 122 has an upper surface 126 which is substantially planar (flat) in the present embodiment and sized so as to permit the maximum degree of physical contact between the components to be tested and the upper surface. Furthermore, the top plate 122 has a number of  
35 elongated cylindrical recesses 130 formed therein and oriented parallel to the upper surface 126 for receiving one or more

heater elements 132 (described further below). The bottom plate 124 and top plate 122 are substantially parallel to one another as well, as shown in Figure 3.

Both the upper and lower housing elements 104, 106 (including the walls 120, top plate 122, and bottom plate 124) in the embodiment of Figures 2 and 3 are preferably constructed from a highly thermally conductive metal. One preferred material is aluminum alloy due to its comparatively light weight, good thermal response and stability, and ease of machining; however, other materials having desirable properties may be substituted. Small surface ridges or diffusion patterns (see Figure 2a) on the inner surfaces 125 of the housing elements 104, 106 can optimally be used to increase the surface area of the plates 122, 124 and aid in refrigerant diffusion so as to make heat transfer more efficient.

Referring again to Figure 3, the mating surfaces 126 of the upper and lower housing elements 104, 106 are machined to permit a smooth, uniform fit and to facilitate sealing. In the present embodiment, the upper and lower elements 104, 106 are welded together to form a seal between the walls 120 of each, although it can be appreciated that other methods of joinder and sealing (such as brazing, threaded fasteners with gaskets, external mechanical clamping arrangements, and adhesives) may be used with equal success. A plurality of threaded penetrations 134 are machined into the bottom plate 124 of the lower housing element 106 to receive threaded compression fitting studs 136. These studs 136 act to guide the nozzle portions 138 of the high pressure lines 114 through the penetrations 134 and align them properly when the platform 100 is assembled. A compression fitting cap 140 threadedly engages each respective stud 136, and captures the line shroud 142 between the inner surface of the cap 140 and the end of the stud 136 so as to form a leak-tight compression fit between the cap 140, stud 136 and shroud 142 when the cap 140 is mechanically tightened. The line shroud 142 is further welded or brazed to its respective high pressure line 114 to complete the seal between the cavity 108 and the atmosphere. An elastomeric or polymer thread sealant (such as LOCKTITE<sup>™</sup> brand sealant or TEFLON<sup>™</sup> tape) may be used if desired to ensure the adequacy of the seal between the threads of each stud 136 and its respective penetration 134.

When the high pressure lines 114 and associated nozzles 138 are assembled into the bottom plate 124 as shown in Figure 3, the nozzles 138 protrude somewhat above the upper surface 146 of the lower plate 124, and are oriented vertically within the cavity 108 so as to impinge coolant directly onto the lower surface 148 of the top plate 122 if desired. The nozzles 138 in the present embodiment are constructed by simply continuing the high pressure lines 114 into the cavity 108, although it can be appreciated that other nozzle configurations (such as an orifice of different diameter than that of the associated high pressure line 114) may be used to accomplish the desired functions of coolant distribution and spray. Note also that the present invention contemplates the use of nozzles 138 of varying height within the cavity 108 to effect more even coolant distribution under certain circumstances, such as where the lower surface of the top plate 122 is curved or of irregular shape.

Also attached to the bottom plate 124 of the lower housing element 106 are a plurality of low-pressure coolant return lines 164 (shown in Figure 2). These lines are larger in diameter than the high-pressure lines to reduce flow resistance (head loss). These return lines are attached to the lower element 106 via standard pipe or compression fittings (such as those previously described) which are installed in a series of perforations 165 located at the gravity low point of

the platform. This location facilitates the return or disposal of liquid coolant which collects on the top surface 146 of the bottom plate 124 within the cavity 108. Furthermore, since the coolant lines are maintained at a substantially lower pressure than the high pressure distribution lines 114, manifold 116, and coolant source, gaseous or mixed-phase coolant naturally flows from the high pressure lines 114 (and associated nozzles 138) into the cavity 108, where it impinges upon the upper plate lower surface 148 and ultimately flows out the return lines 164.

Further shown in Figure 3 are the heater elements 132 used to elevate the temperature of the top surface 126 of the test platform 100. In the present embodiment, electrical (resistive) direct current heater elements are used, such as the Model J97-25 manufactured by Tempco. These heater elements 132 are connected via their electrical leads 133 to an electrical power supply (not shown) via control logic which selectively energizes or de-energizes the elements 132. This type of heater element is chosen due to its comparatively high heat generation capacity (thermal power output), thermal stability, and linearity. The heater elements 132 are installed within respective recesses 130 in the upper housing element 104, and transfer heat energy to the upper housing element 104 and upper surface 126 via conductive, radiative, and to a lesser degree convective heat transfer. However, it will be apparent to one of ordinary skill in the art that any number of different alternative heating devices and methods may be used to elevate the temperature of the platform top surface 126. For example, fluidic heaters (i.e., headers carrying a comparatively higher temperature fluid) or even laser energy could be used to supply heat to the top surface 126 in a controlled fashion.

Referring now to Figure 4, a cross-section of the coolant distribution manifold 116 is shown. The manifold is comprised generally of a hollow cylindrical threaded metallic fitting 150 with a plurality of apertures 152 in the discharge end 154 of the fitting 150. A plurality of high pressure lines 114 terminate at respective apertures 152 in the fitting 150, where the lines 114 are individually joined to the fitting 150 via conventional welding or brazing techniques. The fitting 150 is then joined via the threads 156 on the fitting to a high pressure liquid or gaseous coolant source (such as a cryogenic liquid nitrogen or carbon dioxide rig, or alternatively a freon- or even ammonia-based refrigeration system) which supplies coolant to the manifold 116 and ultimately the test platform cavity 108 via the high pressure lines 114.

Figures 5a-5c illustrate a second embodiment of the thermal platform of the present invention. Referring to Figure 5a, a housing 102 of circular cross-section and generally cylindrical shape is shown. Such a cylindrical shape is especially well suited to testing and conditioning silicon wafers. The housing 102 is comprised of upper and lower housing elements 104, 106 each having a hollowed cylindrical cavity open at one end. When the upper and lower housing elements 104, 106 are mated together as shown in Figure 5a, a single, fully enclosed cylindrical cavity 108 is formed. The upper and lower elements 104, 106 are sealed via welding, brazing, or other comparable techniques previously described.

As shown in Figure 5c, a number of heater element recesses 130 are created radially (e.g., arranged in a spoke-like manner relative to the central longitudinal axis 160 of the platform housing 102 in a plane parallel to the top surface 126 of the platform) within the upper portion of the upper housing element 104 above the cavity 108 to house the heater elements.

Referring again to Figure 5a, each of the nozzles 138 associated with the high pressure distribution lines 114 project vertically upward into the cavity to a height suitable to ensure adequate coolant distribution within the cavity (and impingement of coolant upon the underside of the top plate 122, not shown.)

Figures 6a and 6b show a third embodiment of the thermal platform of the present invention. The two-piece  
5 cylindrical housing 102 (with internal cavity 108) of the embodiment of Figure 5a above is generally used; however, a series of threaded nipples 170 are formed around the periphery 172 of the upper housing element 104 to receive respective high pressure distribution lines 114. The nipples 170 project generally inward toward the longitudinal axis 160 of the housing 102 in the horizontal plane (e.g., in the plane parallel to the top surface 126), but are canted at an angle  $\theta$  ( $\theta$  being  
10 equal to 30 degrees from the radial direction in this embodiment, as shown in Figure 6b) for more uniform coolant distribution. In the vertical plane, the nipples 170 are oriented at a similar angle such that the nozzles 138 spray coolant directly on the underside of the top plate 122 at an oblique angle. While 30 degrees has been chosen for the cant angle in both the vertical and horizontal planes in the present embodiment, it can be appreciated that other angles (and combinations thereof) may be used with equal success.

As in the other embodiments, the high pressure lines 114 of the thermal platform of Figures 6a-6b are mounted  
15 to the nipples 170 using standard threaded compression fittings 136, 140, and are of equal length from the manifold 116 to ensure uniform coolant flow to each portion of the cavity 108. Furthermore, the radial heater element arrangement of the embodiment of Figure 5c is utilized wherein the heater element recesses 130 are interspersed with the nipples 170 such that the coolant sprays into the interstitial areas on the bottom surface of the top plate 122, thereby allowing for uniform heat and coolant distribution. The embodiment of Figure 6 has the advantage of having a somewhat lower overall  
20 height than the embodiment of Figures 5a-5c, although the radial size (i.e., diameter) is increased somewhat.

#### *Method of Operation*

Referring again to Figure 2a, the thermal platform apparatus 100 disclosed above is constructed in such a manner as to maintain a high degree of temperature uniformity across the top surface 126. Additionally, it is desirous for the platform to be able to rapidly raise and lower the top surface temperature in a controlled and predictable fashion, again  
25 maintaining a high degree of uniformity across the top surface 126 at any given time. To accomplish these aims, the temperature of the platform is monitored and controlled (via a closed PID loop or other suitable control mechanism) such that the flow of coolant into the cavity 108 via the distribution line nozzles 138 and energization of the heater elements 132 maintains the platform top surface temperature (or rate of increase/decrease) within a narrow band. In the case of a steady-state temperature, the heater elements 132 are periodically energized or coolant periodically admitted into the  
30 cavity (depending on the desired platform temperature and existing ambient temperature) to maintain the desired value. Coolant flow is adjusted by altering the pressure drop (such as with a valve or variable orifice) between the coolant source (not shown) and the distribution manifold 116. In the case of temperature ramping (e.g., programmed temperature increases or decreases over a given time interval), the heaters 132 are energized and/or coolant is admitted to maintain the rate of temperature change effectively constant until the desired platform temperature is reached. Input to the  
35 heater/coolant control circuitry is accomplished via one or more external thermocouples or resistance temperature

detectors (RTDs) of the type well known in the art (not shown), which are mounted directly onto or within the top surface 126 of the platform.

5 While the above detailed description has shown, described, and pointed out fundamental novel features of the invention as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the devices illustrated may be made by those skilled in the art without departing from the spirit of the invention.

WHAT IS CLAIMED IS:

1. A thermal platform, comprising:  
a housing having;  
walls and an upper plate;  
5 a cavity formed within said housing, said cavity bounded by said walls and said upper plate;  
at least one heating element disposed in substantial proximity to said upper plate;  
a coolant source for providing coolant at a pressure greater than that of said cavity;  
a plurality of coolant distribution lines penetrating said housing for distributing coolant from said coolant source  
within said cavity; and  
10 at least one coolant return line for discharging said coolant from said cavity.
2. The thermal platform of Claim 1, wherein said housing is substantially rectangular in cross-section.
3. The thermal platform of Claim 1, wherein said coolant distribution lines include nozzles such that said  
coolant flowing from said lines into said cavity impinges on an interior surface of said planar upper plate.
4. The thermal platform of Claim 3, wherein said nozzles protrude above the inner surface of at least one  
15 of said walls.
5. The thermal platform of Claim 3, wherein said nozzles penetrate said housing such that the distribution  
of coolant within said cavity is substantially uniform.
6. The thermal platform of Claim 1, wherein said housing is further comprised of upper and lower housing  
elements.
7. The thermal platform of Claim 6, wherein said upper and lower housing elements are welded together  
20 to form a pressure-tight seal for said cavity.
8. The thermal platform of Claim 1, wherein said heating elements are disposed within respective  
recesses within said housing.
9. The thermal platform of Claim 1, wherein said heating elements are electrical resistive heating  
25 elements.
10. The thermal platform of Claim 1, wherein said coolant is a refrigerant.
11. The thermal platform of Claim 10, wherein said coolant source includes a compressor and cooler.
12. The thermal platform of Claim 1, wherein said coolant is taken from the group consisting of liquid  
nitrogen and carbon dioxide.
13. The thermal platform of Claim 1, wherein said coolant flow through individual ones of said coolant  
30 distribution lines is varied in order to maintain precise control of the temperature gradient across said upper plate.
14. A thermal platform housing, comprising:  
a housing body having walls and a top plate, said top plate which is at least in part substantially planar, said  
walls and top plate each having interior and exterior surfaces;

a cavity disposed entirely within said housing body, said cavity bounded by said interior surfaces of said walls and said top plate;

5 a plurality of penetrations through at least one of said walls and communicating with said cavity, said penetrations arranged so as to allow substantially uniform distribution of coolant within said cavity by coolant distribution nozzles installed within said penetrations.

15 15. The thermal platform housing of Claim 14, wherein said housing further includes at least one recess in substantial proximity to said top plate for enclosing one or more heater elements.

16. The thermal platform housing of Claim 15, wherein said penetrations are further arranged to allow impingement of said coolant flowing from said nozzles directly against said interior surface of said top plate.

10 17. A method of controlling the temperature of a thermal platform, wherein said thermal platform includes a housing having at least one heater element, a substantially planar top plate, and cavity disposed therein, comprising the steps of:

providing a plurality of coolant distribution lines connecting a coolant distribution manifold to a plurality of penetrations in said housing;

15 selectively providing coolant at a pressure higher than that existing in said cavity to said manifold in order to induce uniform flow and distribution of said coolant from said manifold into said cavity;

selectively energizing said heaters;

said directing of coolant flow and energization of heaters being performed in response to a signal related to the temperature of said top plate so as to control said temperature as desired.

20 18. The method of Claim 17, wherein said coolant distribution lines are substantially similar in construction and substantially equal in length.

19. The method of Claim 18, wherein said coolant distribution lines include nozzles for spraying said coolant into said cavity.

20. The method of Claim 17, wherein said signal is derived from a closed loop control circuit.

25 21. The method of Claim 17, wherein said step of selectively providing coolant comprises spraying coolant from said plurality of coolant distribution lines to impinge against a surface of said top plate located within said cavity.

22. A method for controlling the temperature of a thermally conductive plate that has top and bottom surfaces, comprising the steps of:

30 automatically directing substantially equivalent volumes of cooling fluid through a plurality of equally sized coolant lines of uniform length;

cooling said plate by spraying said cooling fluid from said coolant lines to impinge against said bottom surface of said plate in a uniform pattern; and

automatically heating the plate by simultaneously applying identical heating energy to uniformly spaced areas of said plate.



23. The method of Claim 22, wherein said cooling fluid is sprayed against the bottom surface of said plate in a cavity located adjacent to said bottom surface.

24. The method of Claim 22, further comprising the steps of:

monitoring the temperature of said plate, and

5 controlling the heating and cooling of said plate responsive to said monitoring step.



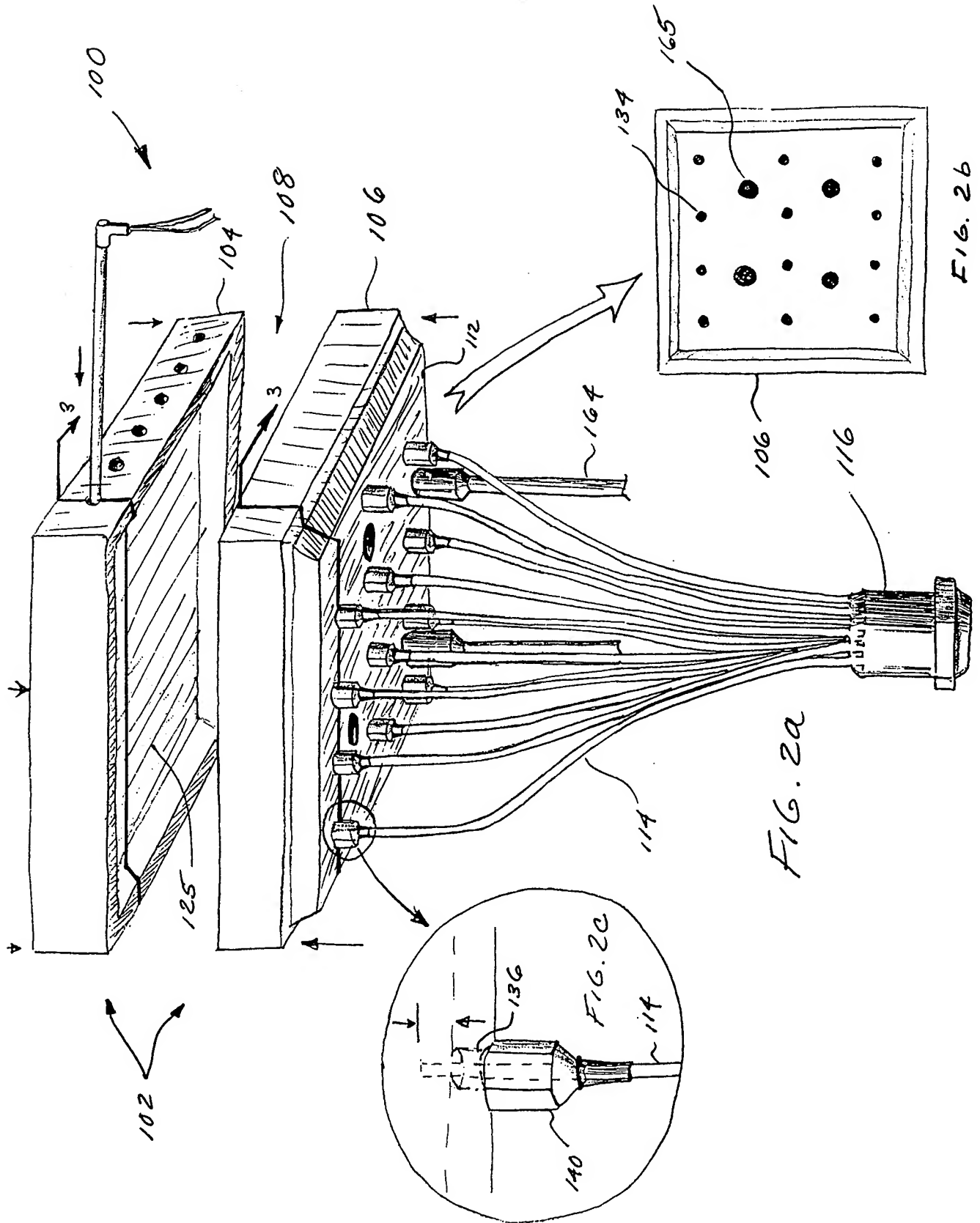
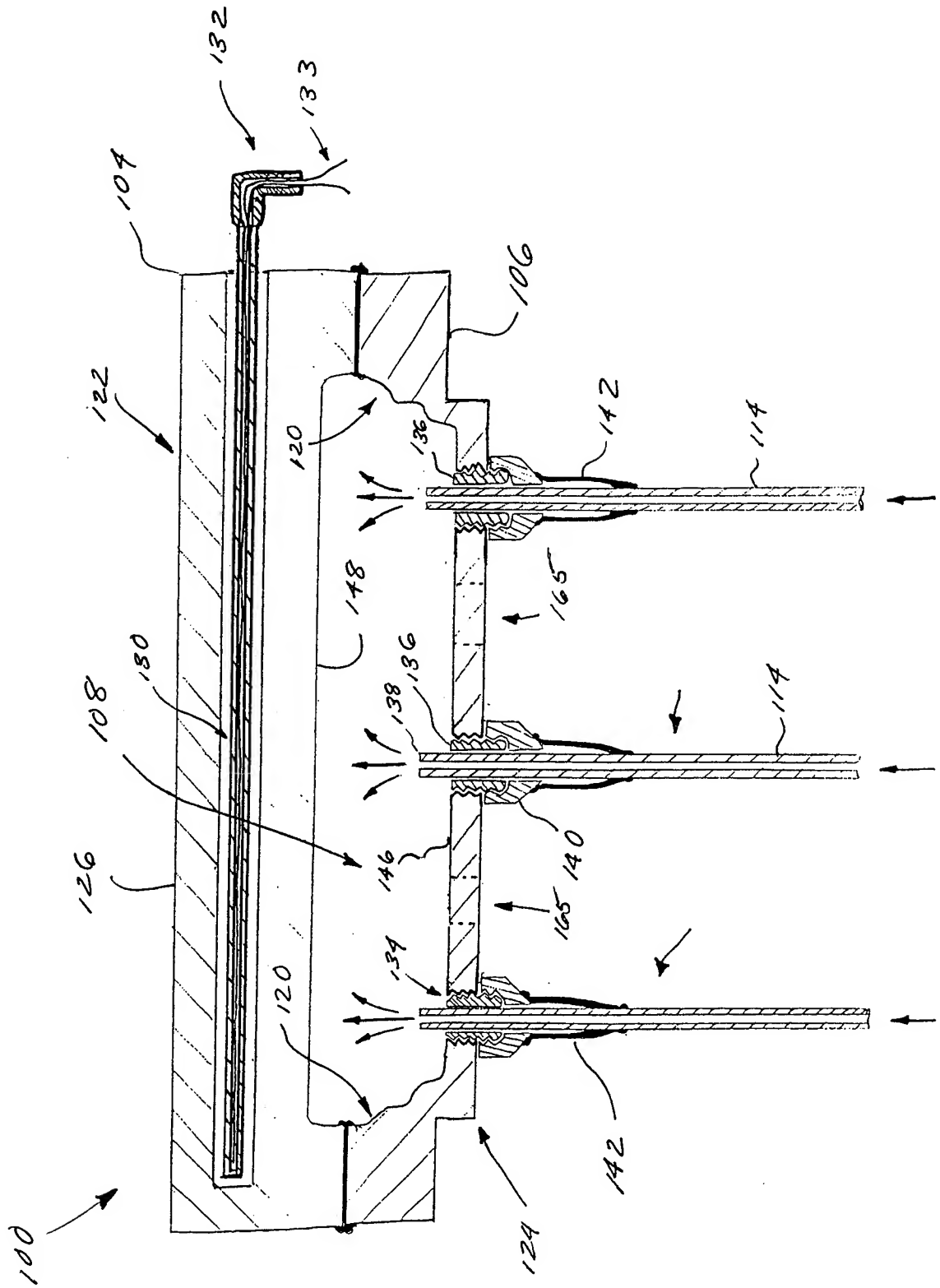


FIG. 3



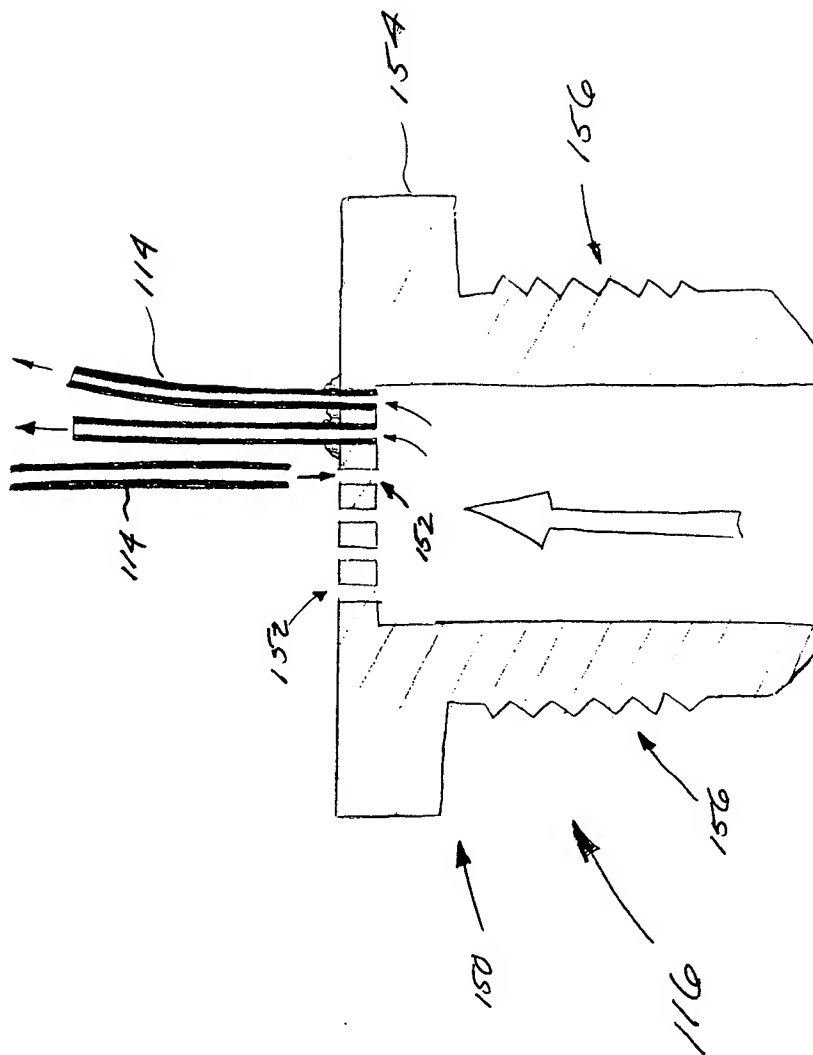


FIG. 4

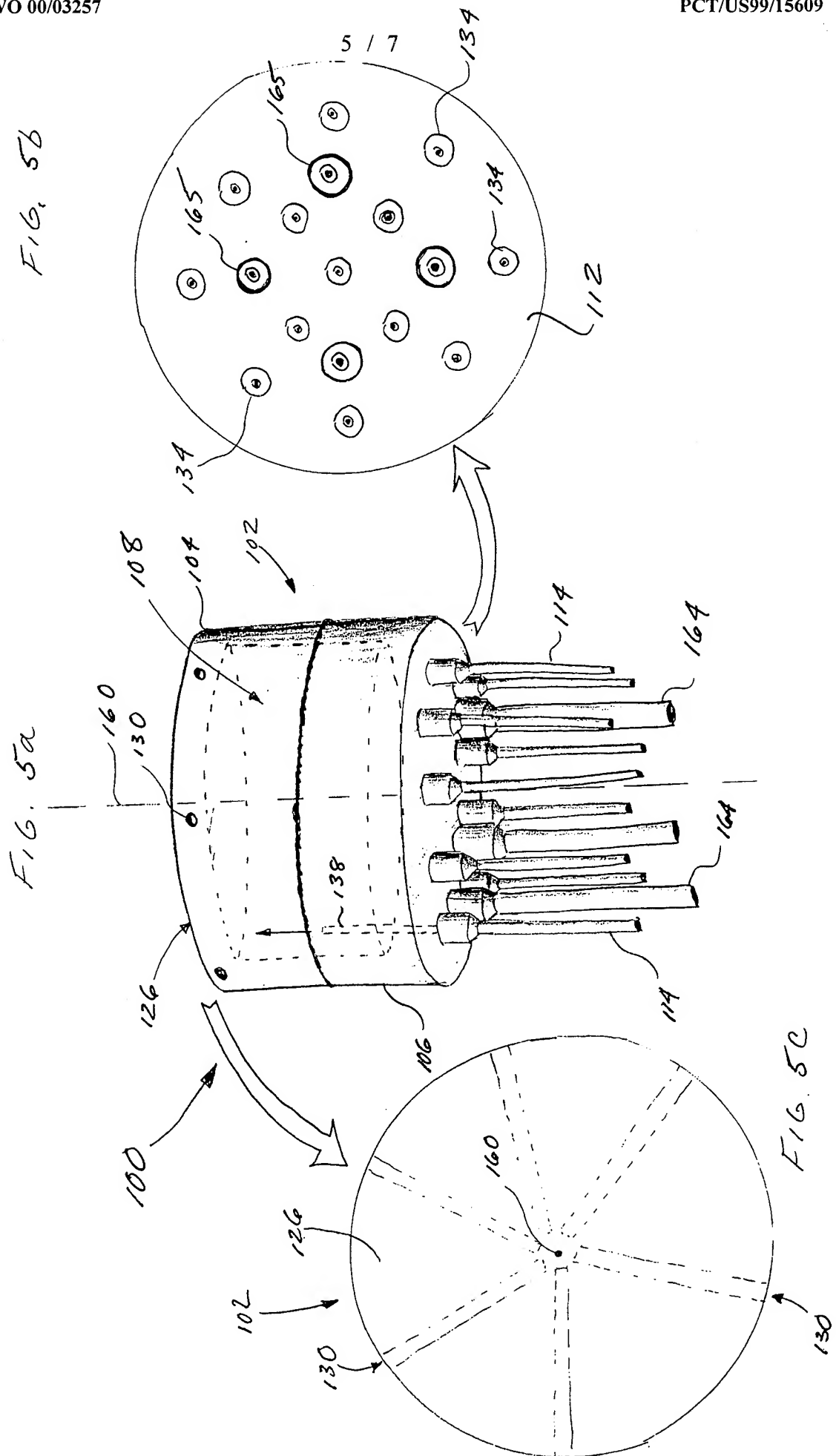
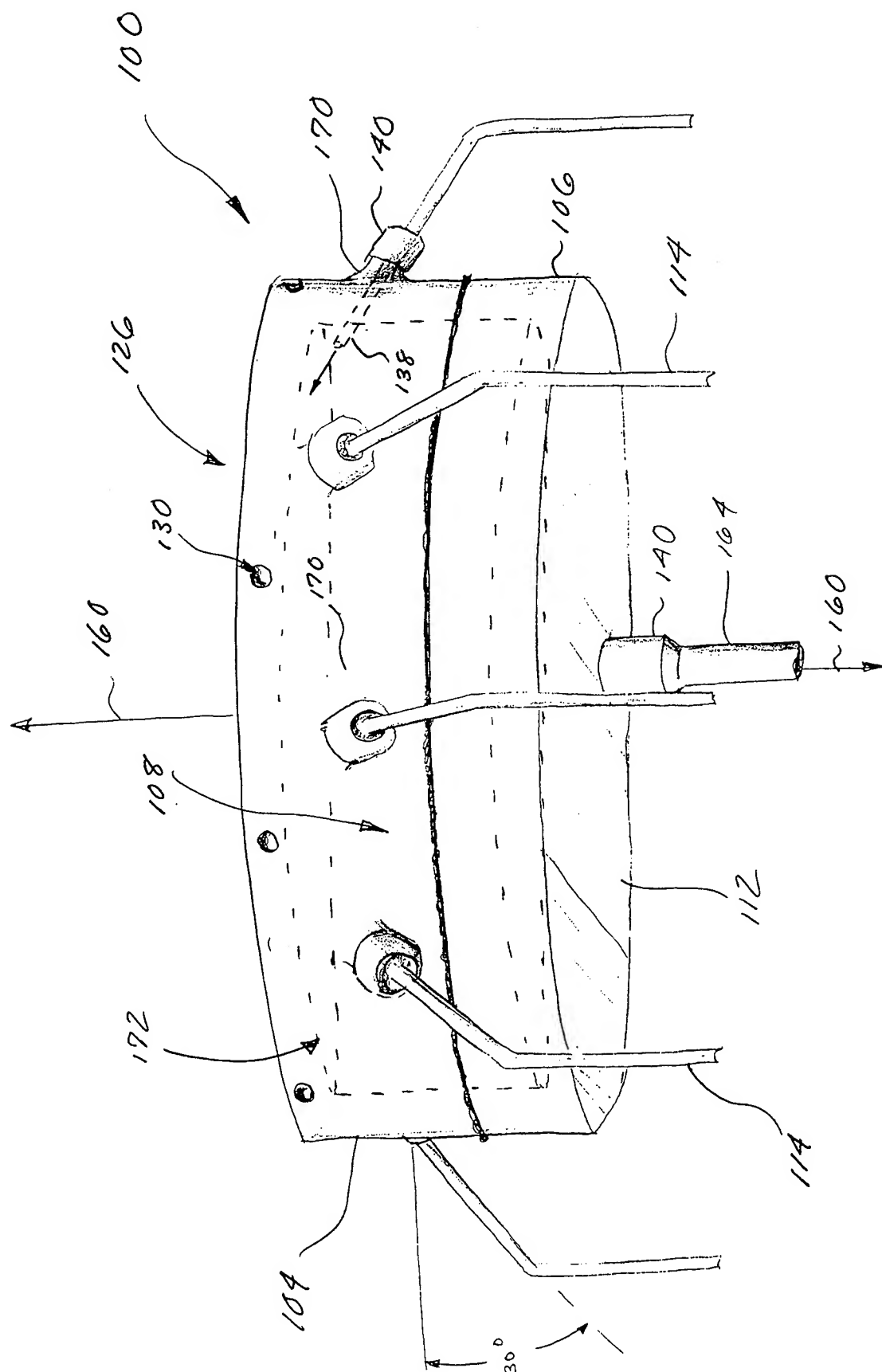


Fig. 6a



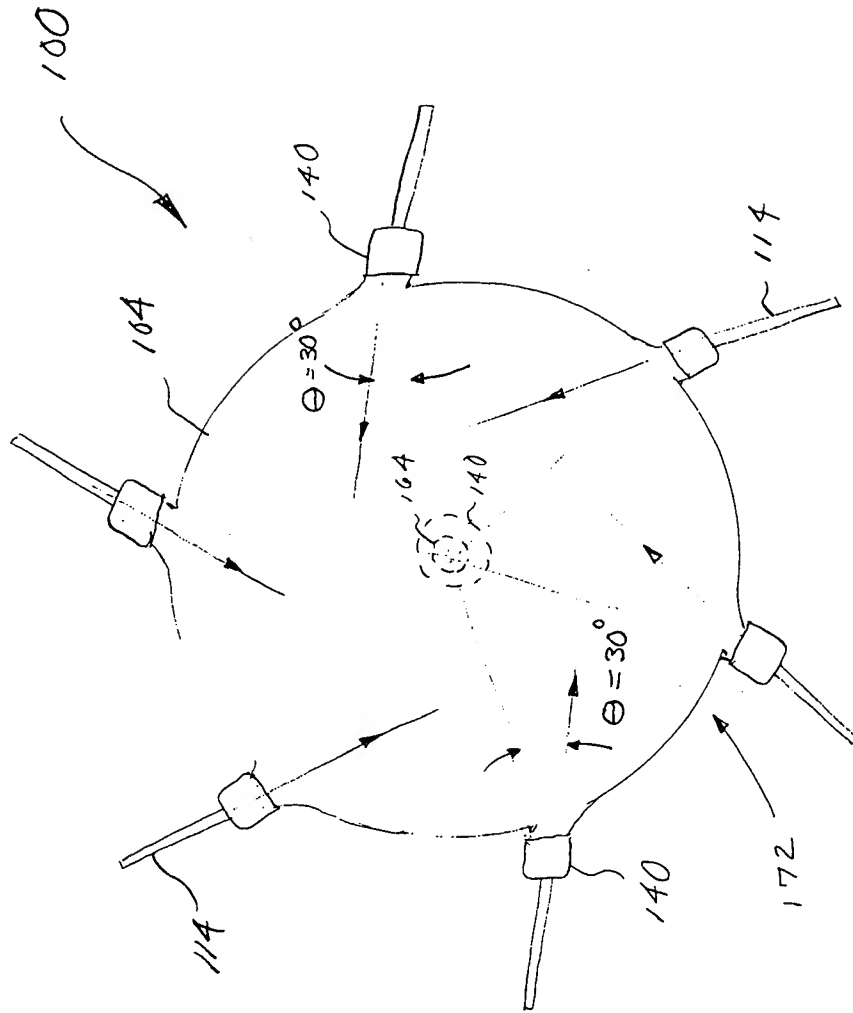


FIG. 6B



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/15609

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 G01R31/28

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 278 495 A (BEATON ET AL.) 11 January 1994 (1994-01-11) figure 1	1,10,14, 17,18,20 2,5,9, 11,12,15
Y	FR 2 227 537 A (LAB. CENTRAL DES IND. ÉLECTRIQUES1) 22 November 1974 (1974-11-22) claim 1	2
Y	DE 19 49 714 A (SCHNELLE) 25 February 1971 (1971-02-25) figure 1	2,5,9, 11,12
Y	US 5 451 884 A (SAUERLAND) 19 September 1995 (1995-09-19) figures 1-3	15



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

10 November 1999

Date of mailing of the international search report

16/11/1999

Name and mailing address of the ISA

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

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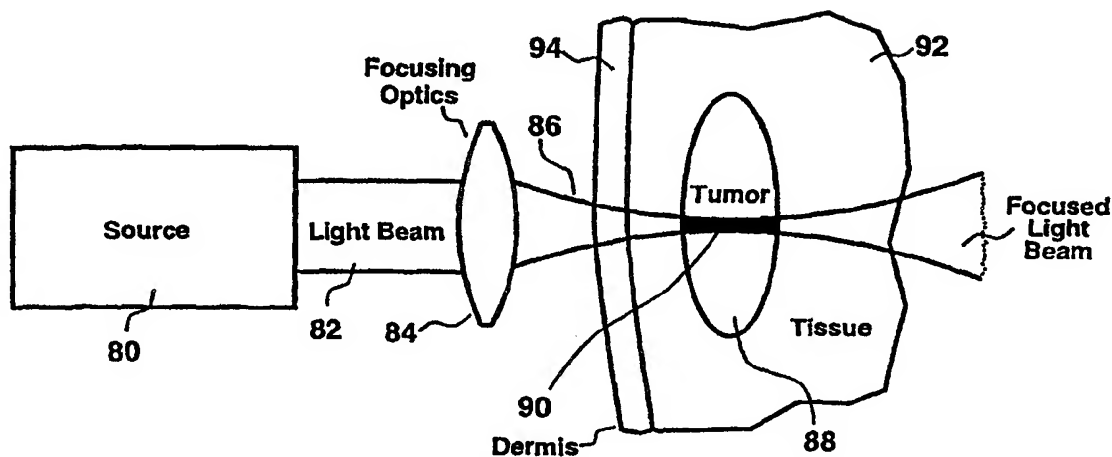
Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5278495	A	11-01-1994	NONE	
FR 2227537	A	22-11-1974	NONE	
DE 1949714	A	25-02-1971	NONE	
US 5451884	A	19-09-1995	JP 7167905 A	04-07-1995



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>A61B 19/00</b>		<b>A1</b>	(11) International Publication Number: <b>WO 00/07514</b>
		(43) International Publication Date: 17 February 2000 (17.02.00)	
(21) International Application Number: PCT/US99/17176 (22) International Filing Date: 29 July 1999 (29.07.99) (30) Priority Data: 09/130,213          6 August 1998 (06.08.98)          US (71) Applicant: PHOTOGEN, INC. [US/US]; 7327 Oak Ridge Highway, Knoxville, TN 37931 (US). (72) Inventors: DEES, H., Craig; Apt. 1517, 1006 Wyndham Way, Knoxville, TN 37923 (US). WACHTER, Eric, A.; 138 Bay Path Drive, Oak Ridge, TN 37830 (US). (74) Agent: MANZO, Edward, D.; Cook, McFarron & Manzo, Suite 2850, 200 West Adams Street, Chicago, IL 60606 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published With international search report.	

(54) Title: TREATMENT OF PIGMENTED TISSUES USING OPTICAL ENERGY



## (57) Abstract

This invention is a method, and apparatus for selectively photo-bleaching or killing pigmented tissues by photochemically converting pigments in the tissues using light (82), and specifically two photon excitation. Photo-toxic products thereby produced then kill pigmented cells. Hyperthermia or an exogenous agent can also be added to augment efficacy. The present invention is also directed to selective thermal destruction of pigmented tissues using related optical means.

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**TREATMENT OF PIGMENTED TISSUES  
USING OPTICAL ENERGY**

## **BACKGROUND OF THE INVENTION**

This is a continuation-in-part of U.S. Patent Application No. 08/739,801, filed on October 30, 1996, entitled "Method for Improved Selectivity In Photoactivation of Molecular Agents".

The present invention is directed to a method and apparatus for treating pigmented tissues by selective photoactivation of pigments in such tissues using optical energy and more specifically two-photon excitation. This selective photoactivation may be used to effect photobleaching of such pigments or to effect photochemical conversion of such pigments into phototoxic products. Photobleaching reduces or eliminates undesirable pigmentation, for example that caused by pigments present in moles, freckles, hair follicles and tattoos. Photochemical conversion produces phototoxic products that destroy pigmented tissues, such as those pigmented tissues in pigmented tumors. The present invention is also directed to selective thermal destruction of pigmented tissues using related optical means.

Photobleaching is the transient or permanent reduction of pigmentation in pigmented tissues upon optical illumination, typically occurring during intense illumination with visible or ultraviolet light. Photobleaching occurs when photoactive pigments are photochemically transformed from a highly colored state to a less highly colored state (depigmentation). For example, photobleaching may be used to reduce or eliminate undesirable pigmentation present in moles and hair follicles or to destroy dyes present in tattoos. It is desired that treated tissues will exhibit localized depigmentation without side effects, such as irritation or cell necrosis. However, previous methods for photobleaching tissues using visible or ultraviolet light have produced undesirable collateral effects, including irritation of surrounding tissues and possible scarring at the treatment site.

In contrast to photobleaching, photochemical conversion of pigments into phototoxic products involves stimulation of localized cell necrosis in treated tissues. This is also effected by optical illumination, typically occurring when intense visible or ultraviolet light is used to illuminate susceptible pigmented tissues. Such localized necrosis may be useful for selective destruction of diseased tissues, such as those present in tumors or benign skin lesions.

More specifically, an important subset of pigmented tissues are pigmented tumors, such as melanomas, which are life threatening and highly difficult to treat. While

melanomas can be treated if detected early using standard surgical, radiation or chemotherapeutic methods, these methods still do not have acceptable levels of effectiveness and produce high levels of collateral damage to normal tissue. Hence, even if detected relatively early, the prognosis is usually poor.

5 Further, if a melanoma has metastasized beyond the primary tumor site, less than 20% of patients will survive beyond five years. For such melanomas, there are no effective therapies. Patients diagnosed with such a metastatic melanoma will survive on average only 3-6 months after the diagnosis even with therapeutic intervention.

10 Further exacerbating the difficulties in treating melanomas is the fact that the incidence of melanoma in Caucasians is increasing at a rate of 6% per year. This is currently the second fastest rate of increase in cancer occurrences -- second only to tobacco related cancers of the lung in women. Currently, the lifetime risk of melanoma in the U.S. is 1 in 75. Accordingly, new effective therapeutic modalities are required to treat both primary and metastatic pigmented tumors such as melanomas.

15 One possible approach for treating pigmented tissues involves the use of melanins, their precursors, and other endogenous or exogenous pigments.

More specifically, there are several pigments in humans that are collectively known as melanins. The function of melanins are to protect tissues from the deleterious effects of electromagnetic radiation (e.g. light). However, melanins and their precursors can also be converted to phototoxic products. For example, a melanin precursor (5-SCD) has been shown to photobind to DNA after exposure to 300 nm (ultraviolet light) illumination. Further, 5-SCD has been shown to be chemically unstable in the presence of ultraviolet (UV) illumination and oxygen, thereby suggesting that phototoxic products of the (1) Type I variety (phototoxic) or the (2) Type II variety (photocatalytic) may be produced.

20 Additionally, many melanoma cells are amelanotic. These cells produce melanin precursors but only small quantities of melanin. Phototoxic damage (induction of single strand breaks) to DNA by at least two precursors to melanin (5-SCD and DIHCA) has been demonstrated upon exposure to UV light. Amelanotic cells will be killed by photodynamic therapy (PDT) performed on such precursors to melanin (e.g., 5-SCD, DIHEA). Thus, melanomas can be killed by delivering energy via light.

25 However, utilization of such phototoxic reactions by illumination of melanin, melanin precursors, or other endogenous pigments has not previously been possible. The UV/Near UV light required for photoactivation is unable to penetrate into normal or

5 cancerous skin (i.e. beyond 2-3 mm.) More specifically, the poor penetration of such light has produced little effect on patients whose skin tumors are larger than or at a depth greater than 3 mm. As a result, only 40-50% of patients whose tumors exceed 3 mm will survive. Accordingly, the survival rate of melanoma patients with tumors whose depth is less than 1 mm is drastically better than those who have tumors which are either located at a depth of greater than 3 mm or extend to a depth greater than 3 mm.

10 Previous photodynamic methods using UV/Near UV light also produced undesirable collateral effects that not only prohibited the photoconversion of melanin and prevented it from killing pigmented tissues but also was potentially dangerous to the patient. For example, UV light can create thymidine dimers which damage genetic material. DNA damage is a major and possibly the sole cause of skin cancers like melanomas. Melanin's absorbance of UV light is designed to prevent this from happening. However, UV light, chemotherapy, and ionizing radiation have recently been shown to increase the virulence of tumor cells. As a result, tumor cells when treated with UV light will have a greater mutation and error rate because the UV light can inactivate mechanisms designed to identify and correct genetic errors (in addition to creating new errors). Therefore, prior techniques were not only unable to effectively kill pigmented tissues by accessing endogenous pigments but also created side effects that could be lethal.

15 In many instances, the effectiveness of various photodynamic processes have been found to be markedly increased by simultaneous photoactivation and localized heating (hyperthermia). Typically, by heating the treatment zone 2-10°C above normal temperatures, the effectiveness of PDT is increased many fold. Such heating alone, however, has not been shown to produce a significant therapeutic effect. In contrast, the inventors of the present invention have conceived that more acute localized heating (i.e., > 2-10°C temperature rise) of tissues and tissue components within the treatment zone may produce a therapeutic effect by causing thermal overload in the treated tissues.

20 Therefore, it is an object of the present invention to provide a method for accessing endogenous pigments in pigmented tissues so as to be able to selectively photobleach said pigments.

25 It is another object of the present invention to provide a method for accessing endogenous pigments in pigmented tissues so as to be able to photochemically convert said pigments into phototoxic products.



It is another object of the present invention to provide a method that will access said endogenous pigments in pigmented tissues without accessing endogenous pigments in healthy tissues surrounding said pigmented tissues.

It is another object of the present invention to provide a method that will augment the effectiveness of said photochemical conversion of said endogenous pigments in said pigmented tissues through the localized application of hyperthermia in said pigmented tissues.

It is another object of the present invention to provide a method that will photothermally destroy pigmented tissues without harming healthy tissues surrounding said pigmented tissues.

### **SUMMARY OF THE INVENTION**

The present invention is directed to a method and apparatus for treatment of a particular volume of tissue or material containing an endogenous pigment. In general, typically, the present invention uses the unique properties of simultaneous two-photon excitation with endogenous pigment in a particular volume of tissue, such as a tumor, to selectively photoactivate the pigment.

This photoactivated pigment may thereby be photobleached or photochemically converted into a phototoxic product. Such photoactivation results from the simultaneous two-photon excitation of the pigment. Preferably, the photons responsible for photoactivation are provided by a laser which produces a beam of light comprising a train of one or more ultrashort pulses. This beam of light can be a focused beam of light if the location and extent of the particular volume of tissue to be treated is precisely known. The focused beam of light can then be scanned throughout the volume of the tissue to treat the entirety of the pigmented tissue. Alternatively, where the location and extent of the pigmented tissue in a volume of tissue is not precisely known, a non-focused light beam can be used.

In an alternative embodiment, an exogenous photodynamic agent can be added to the particular volume of tissue. The exogenous agent can be photoactivated by the simultaneous two-photon excitation. Activation of the exogenous photodynamic agent augments the effectiveness of the endogenous pigment.

In a further alternate embodiment of the invention, the effectiveness of such photoactivation is augmented through the localized application of hyperthermia in the pigmented tissues.

In an additional further alternative embodiment of the invention, the particular volume of tissue is treated with light to promote thermal overload of the pigmented tissues. Thermal overload heats and kills the pigmented tissues.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

In describing the preferred embodiments, reference is made to the accompanying drawings:

FIGURE 1 illustrates an example energy level diagram for simultaneous two-photon excitation;

FIGURE 2 illustrates an example of absorption and scattering properties for animal tissue covering the ultraviolet to infrared spectral region;

FIGURE 3 shows the general trends in optical absorption properties of animal tissue for short wavelength and long wavelength light;

FIGURE 4 illustrates a comparison of optical activation in tissue when single-photon and two-photon excitation methods are used;

FIGURE 5 illustrates an embodiment of the present invention for selective two-photon photoactivation of melanin, melanin-precursors or endogenous pigments using focused light;

FIGURE 6 illustrates an another embodiment for selective two-photon photoactivation of melanin, melanin-precursors, or endogenous pigments using focused light;

FIGURE 7 illustrates a further embodiment for selective two-photon photoactivation of melanin, melanin-precursors, or endogenous pigments using non-focused light;

FIGURE 8 illustrate still another embodiment for selective two-photon photoactivation of melanin, melanin-precursors, or endogenous pigments in a subsurface tissue using non-focused light;

FIGURE 9 illustrates an alternate embodiment for the present invention wherein a focused light beam is used to thermally overload and kill pigmented tumor cells; and

FIGURE 10 illustrates another alternate embodiment for the present invention wherein a non-focused light beam is used to thermally overload and kill pigmented tumor cells.

### **DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENT**

The present invention is directed to a method and apparatus for treating pigmented tissues using light. Such treatment includes the following photochemical outcomes of

therapeutic value: (1) the elimination of undesirable pigmentation in pigmented tissues through photobleaching; and (2) the permanent destruction of pigmented tissues through photochemical conversion of pigments into phototoxic products. More specifically, simultaneous two-photon excitation is used to photochemically convert endogenous or exogenous pigments into desired photoactive products, resulting in the desired photobleaching or tissue destruction. Photobleaching is used to reduce or eliminate undesirable coloration of tissue, such as that in moles, freckles, hair follicles and tattoos. The production of phototoxic products may be used to preferentially kill pigmented tumor cells or other undesirable tissues while sparing normal cells. Significantly, the methods and apparatus in the present invention used for photobleaching and production of phototoxic products utilize equivalent photoactivation mechanisms, differing substantially only in the intended treatment target.

In the preferred embodiment, the present invention uses simultaneous two-photon excitation to photoactivate pigments in the pigmented tissues, yielding photobleached or phototoxic products.

In an alternate preferred embodiment, the present invention uses related optical means to selectively destroy pigmented tissues via photothermal means.

#### Simultaneous Two Photon Excitation

"Simultaneous two-photon excitation" is the non-linear optical excitation occurring as a result of the essentially simultaneous interaction of two photons originating from a single ultrashort laser pulse with one or more agents or pigments to produce one or more photoactivated agents or pigments. "Non-linear optical excitation" means those excitation processes involving the essentially simultaneous interaction of two photons with one or more agents or pigments. "Essentially simultaneous interaction" means those excitation processes occurring as a result of the interaction of one or more agents or pigments with photons provided by a single ultrashort laser pulse. Ultrashort means less than approximately 10 ns.

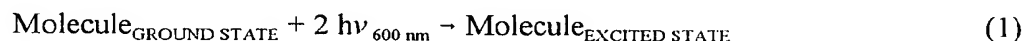
As shown in Figure 1, simultaneous two-photon excitation to an allowed energy level 10 occurs when a photoactive agent is excited from a first allowed electronic energy level 16 upon absorption of a certain energy  $E_1$  that is provided by the simultaneous, combined interaction of two photons 12 and 14 with the agent. If the energies of both photons 12 and 14 are identical, the excitation process is termed "degenerate". The

simultaneous interaction of the two photons is frequently described as being mediated by a transient virtual state 20 with a lifetime on the order of 10 femtoseconds (fs) or less. If both photons do not interact with the agent during this lifetime, excitation does not occur and the agent fails to reach the excited state  $S_n$  (18). Typically, intersystem crossing, IX, subsequently occurs to bring the excited agent to a long-lived activated state  $T_m$  from which a photochemical reaction R can occur.

Simultaneous two-photon excitation may thereby be used to excite processes that normally occur upon absorption of a single UV or visible photon through the simultaneous absorption of two near-infrared photons.

An example of the simultaneous two-photon excitation process is the promotion of melanin precursors from a ground electronic state to an excited electronic state through the simultaneous absorption of two photons at 600 nm, followed by binding of the excited melanin precursor to DNA (this is conventionally excited using a single photon at 300 nm).

In this example, the probability of excitation is related to the product of the instantaneous or peak powers of the first of two photons 12 and the second of two photons 14. This can be conceptualized in the form of a photochemical reaction,



which shows that a molecule in the ground state is promoted to an excited state following simultaneous absorption of two photons at 600 nm,  $h\nu_{600 \text{ nm}}$ . The reaction rate  $R$ , is given by  $R = k [\text{Molecule}_{\text{GROUND STATE}}] [h\nu_{600 \text{ nm}}]^2$ , where  $k$  is a rate constant and where  $[\text{Molecule}_{\text{GROUND STATE}}]$  and  $[h\nu_{600 \text{ nm}}]$  symbolize concentrations of ground state molecules and excitation photons, respectively. Hence, due to the well known quadratic dependence on instantaneous photon irradiance, simultaneous two-photon excitation to an allowed energy level 10 is also referred to as a non-linear excitation process.

A more detailed explanation of simultaneous two-photon excitation and other non-linear and linear processes is described in U.S. patent application no. 08/739,801 filed October 30, 1996 for "Method For Improved Selectivity In Photoactivation Of Molecular Agents" assigned to the same assignee of the present application and which is incorporated herein by reference.

Significance of absorbance and scattering properties in single-photon and simultaneous two-photon processes:

While the cross-section for simultaneous two-photon excitation may be considerably lower than that observed with single-photon excitation, use of the simultaneous two-photon excitation in the present invention may be favorable over single-photon excitation under many conditions because of lower matrix absorption and optical scattering of longer wavelength optical radiation. For example, FIGURE 2 shows the absorption and scattering properties for various components of animal tissue, such as human dermis, covering the ultraviolet (UV) to near infrared (NIR) spectral region.

Specifically, FIGURE 2 demonstrates how higher-energy photons 32 may experience considerably greater tissue absorption than lower-energy photons 34. For example, human skin strongly absorbs higher-energy photons 32 at 400 nm, but is relatively transparent to lower-energy photons 34 at 800 nm. This is a consequence of the natural absorbance of higher-energy photons 32 by blood, pigments, proteins, and genetic materials, among other natural components, of skin.

FIGURE 2 further demonstrates how higher-energy photons 42 may experience considerably greater tissue scatter than lower-energy photons 44. Any optically dense medium, such as human skin, will strongly scatter higher-energy photons 42, for example at 400 nm, but will exhibit much lower scatter for lower-energy photons 44 at 800 nm.

These differences in optical properties have two important consequences. First, absorption of short-wavelength, higher-energy photons 32 by tissue can result in undesirable tissue damage upon exposure to UV or other high-energy light. In contrast, negligible effects may be experienced upon illumination with lower-energy photons 34, such as NIR light, even when the optical power of the NIR light is many-fold higher than

that of the UV light. Secondly, the inherently high absorption and scatter of higher-energy photons 32 by tissue can result in very shallow tissue penetration depths, while lower-energy photons 34 generally have much greater penetration depths.

These important differences in absorption and penetration depth properties for higher-energy and lower-energy light are shown schematically in FIGURE 3. When UV light 50, for example light at 400 nm, impinges on human tissue 52, the majority of the optical energy is immediately absorbed and scattered in the outermost layers 54, such as the epidermis and dermis. Absorption may occur due to excitation of certain molecules in the cells of these outermost layers 54, such as those composing the genetic material in the cellular nucleus. This absorption of higher-energy light by cellular constituents can thereby initiate a variety of collateral photochemical changes 56 in these cells. These collateral photochemical changes 56 resulting from absorption of UV light 50 can include irreversible genetic damage and induction of cancer.

In contrast, NIR light 58, for example at 800 nm, will not be appreciably absorbed or scattered by tissue 52 or its outermost layers 54. The overall depth of penetration will be much greater, and the extent of collateral damage to cells will be substantially lower. Hence, if long-wavelength excitation light is used to replace the higher-energy light used for conventional single-photon excitation, it is possible to photoactivate specific molecules or pigments using relatively non-damaging, high penetration depth, simultaneous two-photon excitation.

Furthermore, the properties of simultaneous two-photon excitation have additional implications when coupled with the inherent non-damaging nature and low absorption of NIR light. For example, FIGURE 4 compares the extent of optically-induced damage in tissue when single-photon excitation 60 and simultaneous two-photon NIR excitation 62 methods are used to illuminate a subcutaneous tumor 64.

Single-photon excitation 60 produces a photoactivation zone 66 that extends substantially along the entire optical path and has no significant biospecificity. Hence, in addition to induction of the desired photoactivation in the tumor 64, collateral damage can occur throughout surrounding tissues, such as the dermis 68 and surrounding healthy tissue 70. If the single-photon excitation 60 is focussed, the photoactivation zone 66 will be slightly enhanced at the focus 72. This photoactivation zone 66, however, might not even extend into the tumor 64 if the UV or visible light is absorbed by the epidermis, dermis 68 or surrounding healthy tissue 70 prior to reaching the tumor 64. This can occur as a consequence of the inherently high absorptivity of tissue at short wavelengths.

In contrast, use of NIR light for simultaneous two-photon excitation 62 produces a sharply defined remote photoactivation zone 74 that is spatially localized at the focus 76 as a consequence of the non-linear properties of this excitation method. Such localization of activation in such a focal zone is a unique property of non-linear excitation processes, such as two-photon excitation. Furthermore, because tissue does not appreciably absorb NIR light, collateral damage to the surrounding dermis 68 and healthy tissue 70 is minimized.

#### Therapeutic applications of simultaneous two-photon excitation:

The foregoing discussion suggests that the fundamental differences in the absorption of UV and NIR light by tissue and cellular constituents, coupled with the special non-linear properties of simultaneous two-photon excitation, have direct applicability for improvements in various medical treatments, specifically in the modification or elimination of pigmented tissues.



Such simultaneous two-photon excitation enables improved localization in the photoactivation of photoactive agents with significantly reduced potential for collateral tissue damage compared with that possible using conventional methods.

Where control of penetration is not critical, non-focussed NIR light may be used to stimulate simultaneous two-photon photoactivation of agents present in a relatively large illuminated area. In such a case, the extent of agent photoactivation is controlled by varying the location, intensity and duration of exposure of such agents to the NIR beam.

Where precise control of penetration depth or volume extent of therapeutic application is more critical, focussed NIR light may be used to stimulate the simultaneous two-photon photoactivation process. In such a case, beam irradiance, exposure duration, and degree of focussing are used to control the extent of agent photoactivation.

In both cases, high-irradiance NIR light may be used to achieve maximum efficacy. Furthermore, the high penetration depths achievable with NIR light combined with the inherent localization of photoactivation that is possible with focused simultaneous two-photon excitation provide a means for photoactivating agents in subsurface tissues without damaging overlying or underlying healthy tissues.

#### Simultaneous Two-Photon Treatment with Endogenous Pigments

The method of the present invention improves on the above-described advantages through the use of simultaneous two-photon excitation to produce a therapeutic outcome based on photoactivation of endogenous pigments in order to treat pigmented tissues. "Endogenous" means pre-existing in a patient or target. "Pigments" means naturally occurring agents that absorb optical energy. Examples of such pigments include melanin, melanin precursors, carotenes, porphyrins (such as hemoglobin), various tattoo dyes and

other optically active species. "Therapeutic outcome" means photobleaching or photodynamic destruction of treated pigmented tissues resulting from the natural biological action of a photoactivated endogenous pigment. "Photobleaching" is the reduction or elimination of undesirable pigmentation, for example that caused by endogenous pigments present in moles, freckles, hair follicles and tattoos. "Photodynamic destruction" is localized tissue necrosis resulting from photochemical production of phototoxic products that destroy pigmented tissues, such as those pigmented tissues in pigmented tumors. Tissues suitable for treatment include pigmented tissues in which a specific therapeutic outcome is desired, such as moles, freckles, pigmented tumors, benign lesions, hair follicles and tattoos.

In a further embodiment of the present invention, a precursor to the endogenous pigments may be used. Examples of such precursors to pigments include 5-S-cysteinyldopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumelanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid. Such precursors have both photoprotective and phototoxic abilities. A metabolic precursor to melanin is a biochemical (e.g. 5-SCD, DHI) that is produced by the cell as part of the synthetic pathway that produces melanin. Melanin precursors, when activated by light, can generate phototoxic products that damage cellular materials (e.g., DNA) killing the target cells. Melanin precursors can be activated by two-photon excitation, as explained supra.

As also explained supra, melanin, melanin precursors, and other endogenous pigments are naturally occurring in human tissue, including in tumors. Such melanins, melanin precursors, or other endogenous pigments can be converted to phototoxic products after exposure to light.

The present invention uses the above-described simultaneous two-photon excitation to specifically target melanin, melanin precursors, or other endogenous pigments in pigmented tissues (such as melanomas and other tumors). The pigment is converted to a phototoxic product by NIR light upon simultaneous two-photon excitation.

5 The phototoxic product then causes damage to the pigmented tissues (by for example photobinding to cellular DNA or causing breaks in this DNA). This kills the cells in the pigmented tissues and, therefore, destroys it. Because simultaneous two-photon excitation is used to specifically target the melanin, melanin precursors, or other endogenous pigments only in the targeted tissue, any melanin, melanin precursors, or  
10 other endogenous pigments in the tissue surrounding the targeted tissue are not converted to phototoxic products.

More specifically, use of simultaneous two-photon excitation produces a sharply defined focal zone that is substantially localized in depth and cross-section. This focal zone can be localized to the targeted tissue (such as a tumor) to be killed or a small zone  
15 within or surrounding this tissue. As a result, photoactivation will only occur in the focal zone (i.e. in the tumor). Hence, any melanin, melanin precursors, or other endogenous pigment not in the targeted tissue, such as for example, in tissue surrounding a tumor, will not be photoactivated because it is outside the focal zone.

20 Additionally, as explained supra, the simultaneous two-photon excitation is able to penetrate deep into normal or cancerous tissue and photoactivate melanin or other endogenous pigments located deep within the tissue. As a result, tumors located deep within the body or large, deep tumors can be reached and destroyed. Destruction of these tumors can be done without activating melanin or other endogenous pigments along the path of the light or surrounding the tumor.

In addition to photodynamic destruction of pigmented tissues, such as those in pigmented tumors, the above-described unique features of simultaneous two-photon excitation may be used to achieve improved safety and specificity in the photobleaching of pigmented tissues, such as in moles, freckles, hair follicles and tattoos. The pigments present in such tissues can be activated by simultaneous two-photon activation, as explained supra, and upon activation may become photobleached. Thus, the present invention also uses simultaneous two-photon excitation to specifically target endogenous pigments in such pigmented tissues, thereby causing photobleaching and a desired reduction or elimination of apparent pigmentation.

It is a specific preferred embodiment of the present invention to employ the output of a NIR source, such as the mode-locked titanium:sapphire laser, to induce simultaneous two-photon photoactivation so as to photoactivate melanin, melanin precursors, or other endogenous pigments using light at a wavelength approximately twice that necessary for such conversion using conventional single-photon photoactivation. As explained supra, such NIR light exhibits improved penetration into tissue relative to that used for conventional single-photon photoactivation, and is less likely to produce collateral damage in tissues adjacent to the desired treatment target.

For the sake of simplicity and clarity, the following descriptions of preferred embodiments will focus on photodynamic destruction of pigmented tumor tissues, such as those in melanomas. However, it is important to note that the methods and apparatus described are equally applicable to the photobleaching of pigmented tissues, such as moles or tattoos, differing substantially only in the intended treatment target. In both classes of treatment, it is the photoactivation of the pigment that is fundamentally responsible for the desired therapeutic outcome.

Accordingly, a preferred embodiment is shown in FIGURE 5. The source 80 produces a beam of light 82 consisting of a rapid series of high peak power pulses of NIR light. For example, standard commercially available mode-locked titanium-sapphire lasers are capable of outputting mode-locked pulses with durations <200 fs and pulse energies of about 1-20 nJ at pulse repetition frequencies in excess of 75 MHz. This source produces a quasi-continuous beam of light having a relatively low average power (up to several Watts) but high peak power (on the order of 100 kW) that is continuously tunable over a NIR wavelength band from approximately 690-1080 nm. The pulse train from the source 80 constitutes a beam of light 82 that is easily focussed using standard optical means, such as reflective or refractive optics 84. The focused beam 86 can then be directed into a tumor 88 or other localized treatment target.

Simultaneous two-photon photoactivation of the melanin, melanin precursors, or other endogenous pigments will be substantially limited to the focal zone 90 of the focused light beam 86 due to the high instantaneous irradiance level that is only present at the focus. Furthermore, regardless of whether melanin, melanin precursors, or another endogenous pigment is present in surrounding healthy tissue 92 or skin 94, insignificant collateral photoactivation, photodamage or conversion into a phototoxic product will occur outside the focal zone 90. This is a consequence of the non-linear relationship between instantaneous optical power and simultaneous two-photon excitation, which limits significant excitation to the focal zone 90. Even if melanin, melanin precursors, or another endogenous pigment is present outside of the focal zone 90, excitation intensities are below that necessary to produce significant photoactivation.

The apparatus of the present invention can also include, for example, a focusing apparatus for focusing the light throughout a range of focal lengths extending from a surface of the tissue to a depth substantially beyond the surface. The source of light and

focusing apparatus cooperate to promote simultaneous two-photon excitation of the pigment at controllable locations throughout the volume of tissue.

By scanning the location of the focus of the beam 86 throughout the volume of the tumor 88, complete photoactivation of the melanin, melanin precursors, or other endogenous pigments into a phototoxic product throughout the tumor 88 can be effected. This scanning action can be produced by changing the position of the focus 86 relative to the tumor 88, or by moving the tumor 88 relative to a stationary focus 86 location. The quality of the focal region 90 of the focused light beam 86 may be improved by pre-expanding the light beam 82, using a beam expander or other device, prior to focusing using standard optical means.

This scanning can be done, for example, by positioning a focus of a beam of light over a range of positions so that a focal plane of the light beam occurs at a site located between a surface of the tissue and a point substantially beyond the tissue surface. As a result, treating the particular volume of tissue may extend to penetrate deep within the tissue. This scanning can further include varying, while the beam of light is extant, the radial position of the focal plane within the tissue, thereby to photoactivate the endogenous pigment at a multiplicity of positions between the tissue surface and a position located substantially beyond the tissue surface.

The simultaneous two-photon photoactivation embodiment of the present invention has several variations for the treatment of topical tissues, as shown in FIGURE 6 and in FIGURE 7. For example, the non-damaging nature of focused NIR light, shown in FIGURE 6, or of non-focused NIR light, shown in FIGURE 7, allows photoactivation of melanin or other endogenous pigments at topical locations without risk to underlying or surrounding tissues.

5 Focused simultaneous two-photon photoactivation of melanin or other endogenous pigments for topical therapy, as shown in FIGURE 6, is effected when a beam of light 82 from a source 80 is focused 86 onto a tumor 88 or other localized treatment target using standard optical means, such as reflective or refractive optics 84. In this manner, photoactivation of the melanin, melanin precursors, or other endogenous pigments into a phototoxic product occurs only at the focal zone 90. The surrounding healthy tissue 92 and skin 94 are unaffected in this process, even if they also contain melanin, melanin precursors, or another endogenous pigment, since photoactivation is substantially limited to the focal zone 90. As described previously, a scanning action can be used to effect photoactivation of the melanin, melanin precursor, or other endogenous pigment into a phototoxic product throughout the volume of the tumor 88.

10 Non-focused simultaneous two-photon photoactivation of melanin, melanin precursors, or other endogenous pigments for topical therapy, as shown in FIGURE 7, is effected when a non-focused or expanded beam of light 96 from a source 80 is directed onto a topical tumor 88 or other localized treatment target. This beam of light 96 may have a cross sectional area smaller than, equal to, or larger than that of the tumor 88. Since melanin, melanin precursors, or other endogenous pigments are present in substantially higher levels in the tumor 88, the therapeutic action will be substantially limited to the volume of the tumor 88. Since the beam of light 96 is non-damaging to tissues that do not contain a significant concentration of pigment, damage to surrounding healthy tissue 92 and skin 94 is avoided. This embodiment may be particularly useful when the exact location, size and shape of the tumor 88 are not known, or when it is otherwise undesirable to carefully control the location of application of the beam of light 96, since careful control of the location of the beam of light 96 is not critical for successful administration of this therapeutic regime. When non-focused light is used, employment

of extremely high peak power excitation sources, such as Q-switched lasers or regeneratively amplified mode-locked lasers, may be beneficial due to their exceptionally high peak radiant power (which is in the GW range) that will thereby afford a high instantaneous irradiance over a large area.

5           A final related variation of this preferred embodiment for simultaneous two-photon photoactivation is shown in FIGURE 8, where a non-focused or expanded beam of light 96 from a source 80 is directed onto a tumor 88 or other localized treatment target located below the skin's surface. This beam of light 96 may have a cross sectional area smaller than, equal to, or larger than that of the tumor 88. Since melanin, melanin precursors, or other endogenous pigments are present in substantially higher levels in a tumor 88, the therapeutic action will be substantially limited to the volume of the tumor 88. Since the beam of light 96 is non-damaging to tissues that do not contain a significant concentration of pigment, damage to surrounding healthy tissue 92 and skin 94 is avoided. This embodiment may also be particularly useful when the exact location, size and shape of the tumor 88 are not known, or when it is otherwise undesirable to carefully control the location of application of the beam of light 96, since careful control of the location of the beam of light 96 is not critical for successful administration of this therapeutic regime. As in the previous non-focused embodiment, employment of extremely high peak power excitation sources may be beneficial due to their exceptionally high peak radiant power and potential high instantaneous irradiance over a large area.

20           Preferably, the simultaneous two-photon excitation will be produced by an ultrashort pulsed NIR laser light having a wavelength of from approximately 450 nm to 1400 nm with a pulse width of from approximately 25 fs to 10 ns and a greater than approximately 1 kHz pulse repetition frequency. Such laser light can be produced by a mode-locked titanium:sapphire laser or related laser sources.



The extent and duration of excitation affected with such sources will be controlled by varying the location, irradiance and duration of application of the light.

The effectiveness of the therapeutic outcome may be markedly increased by simultaneous photoactivation and localized heating (hyperthermia) of the treatment site.

5 Such heating occurs as a secondary effect of illumination with laser light, and may also be controlled by varying the location, irradiance and duration of application of the light, so as to yield heating in the treatment zone of 2-10°C above normal temperatures. For example, application of light at intensities of 150-3000 mW/cm<sup>2</sup> may be used to produce such desirable hyperthermia. Alternately, secondary thermal sources, such as infrared  
10 lamps or warm fluid baths, may be used to effect such desirable hyperthermia at the treatment site.

While the foregoing disclosure has primarily focused on example therapeutic applications using two-photon excitation of agents with ultrashort pulsed NIR light produced by mode-locked titanium:sapphire lasers, the present invention is not limited to  
15 such excitation nor to such narrowly defined optical sources. In fact, aspects of the present invention are applicable when optical excitation is effected using linear or other non-linear methods. For example, various other optical sources are applicable, alone or in combination, such as continuous wave and pulsed lamps, diode light sources, semiconductor lasers; other types of gas, dye, and solid-state continuous, pulsed, or  
20 mode-locked lasers, including: argon ion lasers; krypton ion lasers; helium-neon lasers; helium-cadmium lasers; ruby lasers; Nd:YAG, Nd:YLF, Nd:YAP, Nd:YVO<sub>4</sub>, Nd:Glass, and Nd:CrGsGG lasers; Cr:LiSF lasers; Er:YAG lasers; F-center lasers; Ho:YAG and Ho:YLF lasers; copper vapor lasers; nitrogen lasers; optical parametric oscillators, amplifiers and generators; regeneratively amplified lasers; chirped-pulse amplified lasers;  
25 and sunlight.

In an alternative embodiment, an exogenous photodynamic agent can be added to the patient to be activated in conjunction with the endogenous pigments. "Exogenous" agents are photoactive materials not pre-existent in a patient or other target which are for example administered for the purpose of increasing efficiency of conversion of optical energy into a therapeutic process. Examples of such exogenous agents include Rose Bengal, psoralen derivatives, indocyanine, Lutex,  $\text{Sn}(\text{ET}_2)$  and various porphyrin derivatives, including porfimer sodium and benzoporphyrin derivative. Preferably, the targeted tissue is pretreated with the exogenous agent so that it retains a therapeutic concentration of the agent when the tissue is treated with light so as to promote simultaneous two-photon activation of the agent. Alternatively, the agent can be added at other times during the process. Upon administration and accumulation in targeted tissue, such agents can be used to efficiently interact with NIR light so as to kill tissue by Type I or Type II PDT mechanisms. Such killing can be used to augment or supplement killing of pigmented tissues using endogenous photoactive agents as described supra.

Another alternate embodiment of the present invention is directed to the thermal destruction of melanomas and other pigmented lesions.

Melanomas are usually dramatically darker than surrounding healthy tissue. The dark color associated with melanomas is caused by increased production of melanin by tumor cells. Melanin is a strong absorber of ultraviolet (UV) and visible light, and normally protects cells from the deleterious effects of solar UV radiation. For example, FIGURE 2 shows that melanin is highly absorptive at wavelengths shorter than approximately 1000 nm. In contrast, hemoglobin has minimal absorbance above 450 nm. The high concentration of melanin in most melanoma cells makes them capable of strongly and selectively absorbing light at wavelengths longer than 450 nm and shorter than 1000

nm. Thus, illumination of melanoma cells with light at such wavelengths will produce much more heat in those cells as compared to cells in less pigmented tissue.

Currently, laser illumination is used in cosmetic applications to remove unwanted hair. Laser hair removal is accomplished because there is more pigment in the hair follicles than in surrounding tissue. Therefore, when a laser illuminates the pigmented hair follicle, it absorbs much more of the light, causing localized heating. The localized hyperthermia thereby created in the bulb of the hair follicle kills the hair follicle while sparing surrounding tissue (which is not heated to a significant extent by the laser illumination).

The inventors of the present application have discovered a process to kill pigmented tumor cells by thermally overloading them whereas the relatively unpigmented cells in healthy tissues surrounding the tumor are spared. Figs. 9 and 10 illustrate such an alternate embodiment for the present invention wherein a focused light beam 86 (Fig. 9) and a non-focused light beam 96 (Fig. 10), respectively, are used to kill pigmented tumor cells 98. Such pigmented tumor cells 98 may be located at the surface of tissue 92 to be treated, or may be located significantly below the surface. Illumination of pigmented tumor cells 98 may be effected using a continuous wave or pulsed laser source operating in either of two wavelength bands between approximately 450 and 800 nm and between approximately 800 and 1400 nm.

For wavelengths between 450 and 800 nm, direct linear excitation of melanin is used to selectively promote thermal overload of pigmented tumor cells 98. Light in this band is preferred when pigmented tumor cells 98 are located at the surface of tissue or at depths of approximately 2 mm or less below the surface since such light is not capable of penetrating tissue to significantly greater depths. For such excitation, it is preferred that illumination be effected via application of one or more short pulses of light having a pulse

duration of 10 ns (nanoseconds) or less, and more preferably of 10 ps (picoseconds) or less. Use of such short duration pulses reduces thermal loss to surrounding tissues, thereby improving efficiency in selective thermal overload of the pigmented tumor cells 98. It is further preferred that the wavelength of this light be between approximately 600 and 800 nm to afford improved specificity for excitation of melanin relative to hemoglobin. Moreover, it is further preferred that such light be produced by a light source such as a mode-locked titanium:sapphire laser, which is readily able to deliver such light pulses at such wavelengths. A focused light beam 86 is preferable where the location and extent of the lesion is precisely known, since improved control over the extent of the treatment zone is thereby possible. By scanning this focused light beam 86 throughout the volume of the tumor, it is possible to treat the entirety of the pigmented tumor cells 98. However, where the location and extent of the lesion is not precisely known, or where the lesion is exceptionally large, use of a non-focused light beam 96 is preferred to assure that treatment is effected in all of the pigmented tumor cells 98.

For wavelengths between 800 and 1400 nm, excitation of melanin via linear mechanisms and non-linear two-photon mechanisms is used to selectively promote thermal overload of pigmented tumor cells 98. Light in this band is preferred when pigmented tumor cells 98 are located below the surface of tissue at depths of approximately 2 mm or greater since such light is capable of penetrating tissue to such depths. For such excitation, it is preferred that illumination be effected via application of one or more short pulses of light having a pulse duration of 10 ps or less, and more preferably of 1 ps or less. Use of such short duration pulses increases the efficiency of non-linear excitation mechanisms while simultaneously reducing thermal loss to surrounding tissues, thereby improving efficiency in selective thermal overload of the pigmented tumor cells 98. A focused light beam 86 is preferable where the location and extent of the lesion is precisely

known, since improved control over the extent of the treatment zone is thereby possible. Use of such a focused light beam 86 improves efficiency of non-linear excitation mechanisms, allowing relatively low energy light sources 80, such as mode-locked titanium:sapphire lasers, to be successfully used. By scanning this focused light beam 86 throughout the volume of the tumor it is possible to treat the entirety of the pigmented tumor cells 98. However, where the location and extent of the lesion is not precisely known, or where the lesion is exceptionally large, use of a non-focused light beam 96 is preferred to assure that treatment is effected in all of the pigmented tumor cells 98. Under such illumination conditions, amplified or other higher energy light sources 80, such as the regeneratively amplified mode-locked titanium:sapphire laser, are preferred so as to increase illumination intensities to levels sufficient to achieve efficient non-linear excitation.

It will be clear that the methods and apparatus described for this alternate embodiment will be equally applicable to the treatment of other pigmented blemishes, such as for example moles, port wine stains, freckles, scars, and tattoos, and for the reduction or elimination of pigments in hair.

While the present invention has been illustrated and described as embodied in general methods and apparatus for killing pigmented tumors by activation of endogenous pigments using optical radiation, it is not intended to be limited to the details shown, since it will be understood that various omissions, modifications, substitutions and changes in the forms and details of the method illustrated and in its operation can be made by those skilled in the art without departing in any way from the spirit of the present invention.

This description has been offered for illustrative purposes only and is not intended to limit the invention of this application, which is defined in the claims below.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

We claim:

Claim 1. A method for the treatment of a particular volume of tissue, said volume of tissue containing an endogenous pigment, the method comprising the steps of:  
treating the particular volume of tissue with light to promote a simultaneous two-photon photoactivation of said pigment in the particular volume of tissue, wherein the pigment becomes photochemically activated in the particular volume of tissue.

Claim 2. The method of Claim 1 wherein the light to promote said simultaneous two-photon photoactivation is a laser light produced by a laser.

Claim 3. The method of Claim 2 wherein the laser light comprises a train of one or more ultrashort pulses.

Claim 4. The method of Claim 2 including operating the laser to produce light at a wavelength between approximately 450 nm to 1400 nm.

Claim 5. The method of Claim 1 wherein the light to promote said simultaneous two-photon photoactivation is a focused beam of light.

Claim 6. The method of Claim 5 wherein the focused beam of light is focused laser light.

Claim 7. The method of Claim 6 wherein said particular volume of tissue is located substantially at the tissue surface.

Claim 8. The method of Claim 6 wherein said particular volume of tissue is located substantially below the tissue surface.

5        Claim 9. The method of Claim 1 wherein said step of treating the particular volume of tissue includes positioning a focus of a beam of light over a range of positions so that a focal plane of the light beam occurs at a site located between a surface of the tissue and a point substantially beyond the tissue surface, whereby said step of treating the particular volume of tissue may extend to penetrate deep within the tissue.

10        Claim 10. The method of Claim 9 further including varying, while the beam of light is extant, the radial position of the focal plane within the tissue, thereby to photoactivate the endogenous pigment at a multiplicity of positions between the tissue surface and a position located substantially beyond the tissue surface.

15        Claim 11. The method of Claim 1 wherein said endogenous pigment becomes photoactivated in said particular volume at a controllable position substantially beyond a tissue surface.

20        Claim 12. The method of Claim 1 further comprising the step of controlling the photoactivation by varying the location, irradiance and duration of said light.

Claim 13. The method of Claim 1 wherein the light to promote said simultaneous two-photon excitation of the endogenous pigment is a non-focused beam of light.



Claim 14. The method of Claim 13 wherein said particular volume of tissue is located substantially at the tissue surface.

5      Claim 15. The method of Claim 13 wherein said particular volume of tissue is located substantially below the tissue surface.

10      Claim 16. The method of Claim 1 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

15      Claim 17. The method of Claim 16 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumelanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

20      Claim 18. The method of Claim 16 wherein said porphyrins include hemoglobin.

25      Claim 19. A method for producing a photoactivated product in a particular volume of a material, the method comprising treating the particular volume of the material with light to promote a simultaneous two-photon excitation of an endogenous pigment contained in the particular volume of the material, wherein the pigment becomes a photoactivated product in the particular volume of the material.

30      Claim 20. The method of Claim 19 wherein the light to promote said simultaneous two-photon photoactivation is a laser light produced by a laser.

Claim 21. The method of Claim 20 wherein the laser light comprises a train of one or more ultrashort pulses.

Claim 22. The method of Claim 20 including operating the laser to produce light at a wavelength between approximately 450 nm to 1400 nm.

Claim 23. The method of Claim 19 wherein the light to promote said simultaneous two-photon photoactivation is a focused beam of light.

Claim 24. The method of Claim 23 wherein the focused beam of light is focused laser light.

Claim 25. The method of Claim 24 wherein said particular volume of material is tissue located substantially at the surface of said material.

Claim 26. The method of Claim 24 wherein said particular volume of material is tissue located substantially below the surface of said material.

Claim 27. The method of Claim 19 wherein said step of treating the particular volume of material includes positioning a focus of a beam of light over a range of positions so that a focal plane of the light beam occurs at a site located between a surface of the material and a point substantially beyond the material surface, whereby said step of treating the particular volume of material may extend to penetrate deep within the material.

Claim 28. The method of Claim 27 further including varying, while the beam of light is extant, the radial position of the focal plane within the material, thereby to photoactivate the endogenous pigment at a multiplicity of positions between the material surface and a position located substantially beyond the material surface.

5

Claim 29. The method of Claim 19 wherein said endogenous pigment becomes photoactivated in said particular volume at a controllable position substantially beyond a material surface.

10

Claim 30. The method of Claim 19 further comprising the step of controlling the photoactivation by varying the location, irradiance and duration of said light.

15

Claim 31. The method of Claim 19 wherein the light to promote said simultaneous two-photon excitation of the endogenous pigment is a non-focused beam of light.

Claim 32. The method of Claim 31 wherein said particular volume of material is located substantially at the surface of said material.

20

Claim 33. The method of Claim 31 wherein said particular volume of material is tissue located substantially below the surface of said material.

25

Claim 34. The method of Claim 19 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

Claim 35. The method of Claim 34 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumalanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

5

Claim 36. The method of Claim 34 wherein said porphyrins include hemoglobin.

Claim 37. A method for treatment of tissue wherein the tissue includes an endogenous pigment, the method comprising the steps of:

10 directing light to specific regions of interest within the tissue, including regions substantially below a tissue surface, said light being selected to penetrate the tissue and to promote two-photon excitation substantially only at a focal zone;

controlling the location of said focal zone over a range of depths within said tissue;  
and

15 using two-photon excitation, photoactivating said pigment over said range of depths within said tissue, thereby producing a photoactivated product substantially only at the focal zone.

Claim 38. The method of Claim 37 wherein said directing step includes  
20 directing a laser light produced by a laser to said regions of interest.

Claim 39. The method of Claim 38 wherein the laser light comprises a train of one or more ultrashort pulses.

Claim 40. The method of Claim 38 including operating the laser to produce light at a wavelength between approximately 450 nm to 1400 nm.

5        Claim 41. The method of Claim 37 wherein the light to promote said two-photon photoactivation is a focused beam of light.

Claim 42. The method of Claim 41 wherein the focused beam of light is focused laser light.

10       Claim 43. The method of Claim 42 wherein said regions of interest are located substantially at the tissue surface.

Claim 44. The method of Claim 42 wherein said regions of interest are located substantially below the tissue surface.

15       Claim 45. The method of Claim 42 further comprising the step of scanning said regions of interest with said focused beam of light to promote two-photon excitation throughout said regions of interest.

20       Claim 46. The method of Claim 37 wherein said endogenous pigment becomes photoactivated in said focal zone at a controllable position substantially beyond a tissue surface.

25       Claim 47. The method of Claim 37 wherein said two-photon photoactivation is simultaneous two-photon activation.

Claim 48. The method of Claim 37 further comprising the step of controlling the photoactivation by varying the location, irradiance and duration of said light.

Claim 49. The method of Claim 37 wherein the light to promote said two-photon excitation of the photoactive agent is a non-focused beam of light.

Claim 50. The method of Claim 49 wherein said regions of interest are located substantially at the tissue surface.

Claim 51. The method of Claim 49 wherein said regions of interest are located substantially below the tissue surface.

Claim 52. The method of Claim 37 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

Claim 53. The method of Claim 52 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumalanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

Claim 54. The method of Claim 52 wherein said porphyrins include hemoglobin.

Claim 55. A method for the treatment of a particular volume of tissue, said volume of tissue containing an endogenous pigment, the method comprising the steps of:

treating the particular volume of tissue with light to promote thermal overload of pigmented cells in the particular volume of tissue, wherein said thermal overload kills said pigmented cells.

5                   Claim 56.       The method of Claim 55 wherein the light to promote said thermal overload is a laser light produced by a laser.

Claim 57.       The method of Claim 56 wherein the laser light comprises a train of one or more ultrashort pulses.

10                   Claim 58.   The method of Claim 56 including operating the laser to produce light at a wavelength between approximately 450 nm to 800 nm.

Claim 59.   The method of Claim 58 wherein said wavelength of light is between  
15 approximately 600 nm and 800 nm.

Claim 60.   The method of Claim 58 wherein said particular volume of tissue is located substantially at the tissue surface.

20                   Claim 61.   The method of Claim 58 wherein said particular volume of tissue is located approximately 2 mm or less below the tissue surface.

Claim 62.   The method of Claim 58 wherein said laser light has a pulse duration of less than 10 ns.

Claim 63. The method of Claim 62 wherein said laser light has a pulse duration of less than 10 ps.

Claim 64. The method of Claim 56 including operating the laser to produce light at a wavelength between approximately 800 nm to 1400 nm.

Claim 65. The method of Claim 64 wherein said particular volume of tissue is located approximately 2 mm or greater below the tissue surface.

Claim 66. The method of Claim 64 wherein said laser light has a pulse duration of less than 10 ps.

Claim 67. The method of Claim 66 wherein said laser light has a pulse duration of less than 1 ps.

Claim 68. The method of Claim 55 wherein the light to promote said thermal overload is a focused beam of light.

Claim 69. The method of Claim 68 wherein the focused beam of light is focused laser light.

Claim 70. The method of Claim 68 wherein said step of treating the particular volume of tissue includes scanning said particular volume of tissue with said focused beam of light so as to promote thermal overload throughout said particular volume of tissue.



Claim 71. The method of Claim 55 wherein the light to promote said thermal overload is a non-focused beam of light.

Claim 72. The method of Claim 55 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

Claim 73. The method of Claim 72 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumelanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

Claim 74. The method of Claim 72 wherein said porphyrins include hemoglobin.

Claim 75. A method for treatment of a particular volume of tissue, said volume of tissue containing an endogenous pigment and an exogenous photodynamic agent, the method comprising the steps of:

treating the particular volume of tissue with light to promote a simultaneous two-photon photoactivation of said pigment and said agent in said particular volume of tissue, wherein the pigment becomes photochemically converted into a phototoxic product in the particular volume of tissue and said photodynamic agent becomes photoactivated in the particular volume of tissue.

Claim 76. The method of Claim 75 wherein said exogenous photodynamic agent is selected from the group comprising Rose Bengal, psoralen derivatives, indocyanine,

Lutex,  $\text{Sn(ET)}_2$ , and various porphyrin derivatives, including porfimer sodium and benzoporphyrin derivative.

5        Claim 77. The method of Claim 75 wherein the particular volume of tissue is pretreated with said exogenous photodynamic agent such that the particular volume of tissue retains a portion of said agent at the time the particular volume of tissue is treated with light so as to promote simultaneous two-photon activation of said agent.

10       Claim 78. Apparatus for treating a particular volume of tissue containing an endogenous pigment, the apparatus comprising:

15       a source of light and light delivery apparatus for directing light at and into said particular volume of tissue, said light being selected in frequency and energy to promote simultaneous two-photon excitation of said endogenous pigment so that said pigment becomes photochemically activated in said particular volume of tissue.

20       Claim 79. The apparatus of Claim 78 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

25       Claim 80. The apparatus of Claim 79 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyldopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumalanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

30       Claim 81. The apparatus of Claim 79 wherein said porphyrins include hemoglobin.

Claim 82. The apparatus of Claim 79 wherein said source of light is a laser light produced by a laser.

5      Claim 83. The apparatus of Claim 82 wherein said laser light comprises a train of one or more ultrashort pulses.

Claim 84. The apparatus of Claim 82 wherein said laser light has a wavelength between approximately 450 nm to 1400 nm.

10      Claim 85. The apparatus of Claim 78 wherein said particular volume of tissue is located substantially at the tissue surface.

Claim 86. The apparatus of Claim 78 wherein said particular volume of tissue is located substantially below the tissue surface.

15      Claim 87. The apparatus of Claim 78 wherein said light is non-focused light.

20      Claim 88. The apparatus of Claim 78 further comprising a focusing apparatus for focusing the light throughout a range of focal lengths extending from a surface of said tissue to a depth substantially beyond said surface, said source of light and focusing apparatus cooperating to promote simultaneous two-photon excitation of said pigment.

Claim 89. The apparatus of Claim 78 further comprising an exogenous photodynamic agent in said particular volume of tissue, said light being selected in

frequency and energy to promote simultaneous two-photon activation of said agent so that said agent becomes photoactivated in the particular volume of tissue.

5        Claim 90. The apparatus of Claim 89 wherein said exogenous photodynamic agent is selected from the group comprising Rose Bengal, psoralean, indocyanine, Lutex, Sn(ET)<sub>2</sub> and various porphyrin derivatives, including porfimer sodium and benzoporphyrin derivative.

10       Claim 91. An apparatus for treating a particular volume of tissue containing an endogenous pigment, the apparatus comprising:

15       a source of light and light delivery apparatus for directing light at and into said particular volume of tissue, said light being selected to promote thermal overload of pigmented cells in the particular volume of tissue, wherein said thermal overload kills said pigmented cells.

20       Claim 92. The apparatus of Claim 91 wherein said source of light is a laser light produced by a laser.

25       Claim 93. The apparatus of Claim 92 wherein said laser light comprises a train of one or more ultrashort pulses.

30       Claim 94. The apparatus of Claim 92 wherein said laser light has a wavelength between approximately 450 nm to 1400 nm.

Claim 95. The apparatus of Claim 91 wherein said particular volume of tissue is located substantially at the tissue surface.

5      Claim 96. The apparatus of Claim 91 wherein said particular volume of tissue is located substantially below the tissue surface.

10      Claim 97. The method of Claim 1 further comprising the step of heating said volume of tissue using said light so to produce a hyperthermic effect and controlling the hyperthermic effect by varying the location, irradiance and duration of said light so as to augment the effectiveness of said photoactivation.

15      Claim 98. The method of Claim 19 further comprising the step of heating said volume of material using said light so to produce a hyperthermic effect and controlling the hyperthermic effect by varying the location, irradiance and duration of said light so as to augment the effectiveness of said photoactivation.

Claim 99. The method of Claim 1 wherein said photochemical activation of said pigment includes conversion of said pigment into a phototoxic product.

20      Claim 100. The method of Claim 1 wherein said photochemical activation of said pigment includes photobleaching of the pigment in said tissue.

Claim 101. The method of Claim 100 wherein said tissue is selected from the group comprising moles, freckles, hair follicles and tattoos.

Claim 102. The method of Claim 19 wherein said photoactivated product is a phototoxic product.

5        Claim 103. The method of Claim 19 wherein said photoactivation of said pigment includes photobleaching of the pigment in said material.

Claim 104. The method of Claim 103 wherein said material is selected from the group comprising moles, freckles, hair follicles and tattoos.

10        Claim 105. The method of Claim 37 wherein said photoactive product is a phototoxic product.

Claim 106. The method of Claim 37 wherein said photoactivating of said pigment includes photobleaching of said pigment in said tissue.

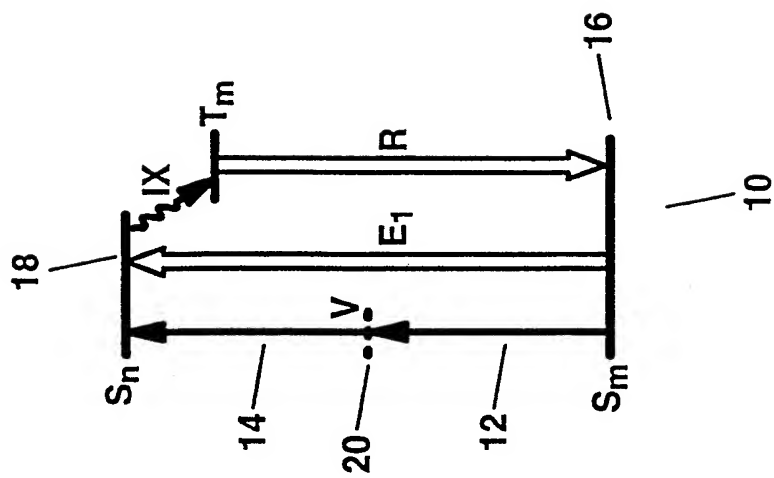
15        Claim 107. The method of Claim 106 wherein said tissue is selected from the group comprising moles, freckles, hair follicles and tattoos.

20        Claim 108. the apparatus of Claim 78 wherein said photochemical activation of said pigment includes conversion of said pigment into a phototoxic product.

Claim 109. The apparatus of Claim 78 wherein said photochemical activation of said pigment includes photobleaching of the pigment in said tissue.

Claim 110. The apparatus of Claim 109 wherein said tissue is selected from the group comprising moles, freckles, hair follicles, and tattoos.

**Fig. 1.**





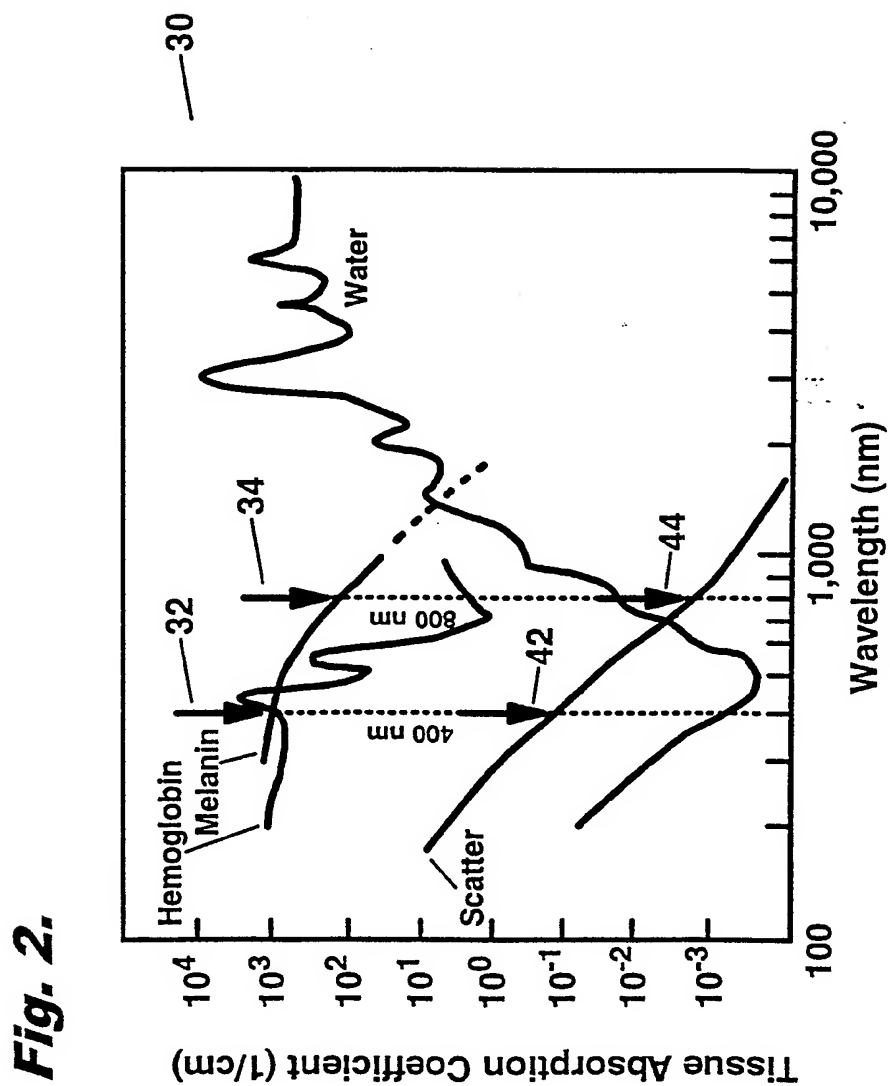
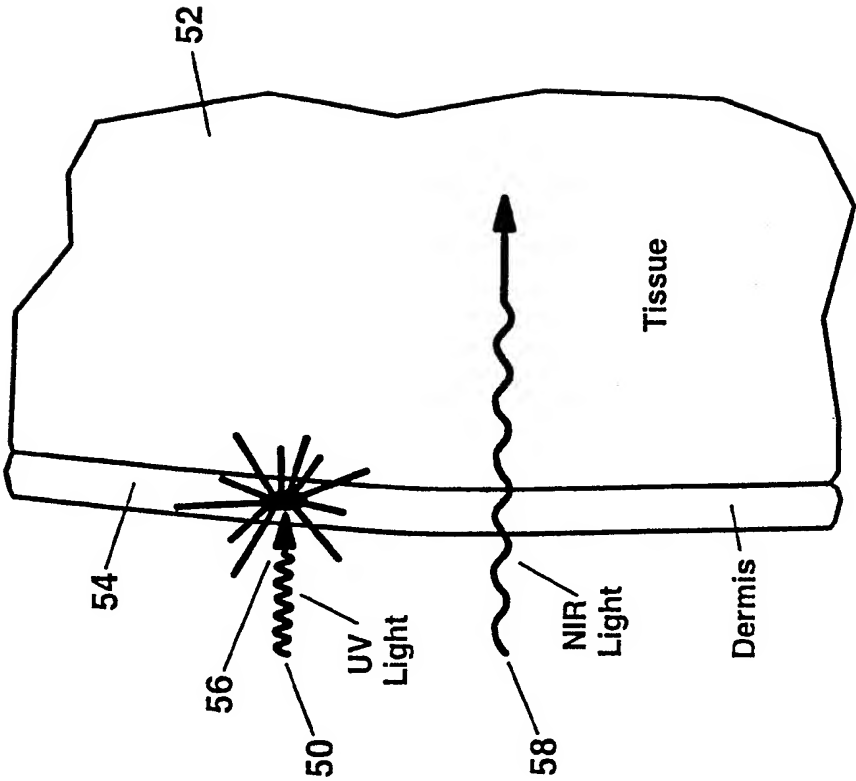
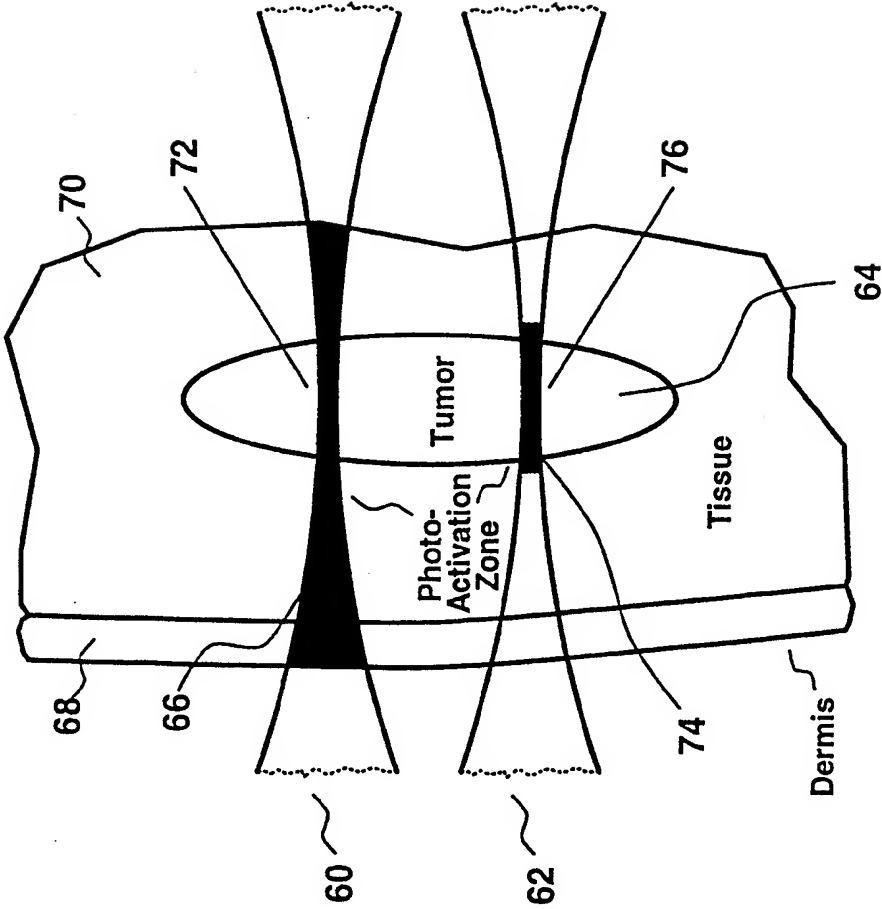


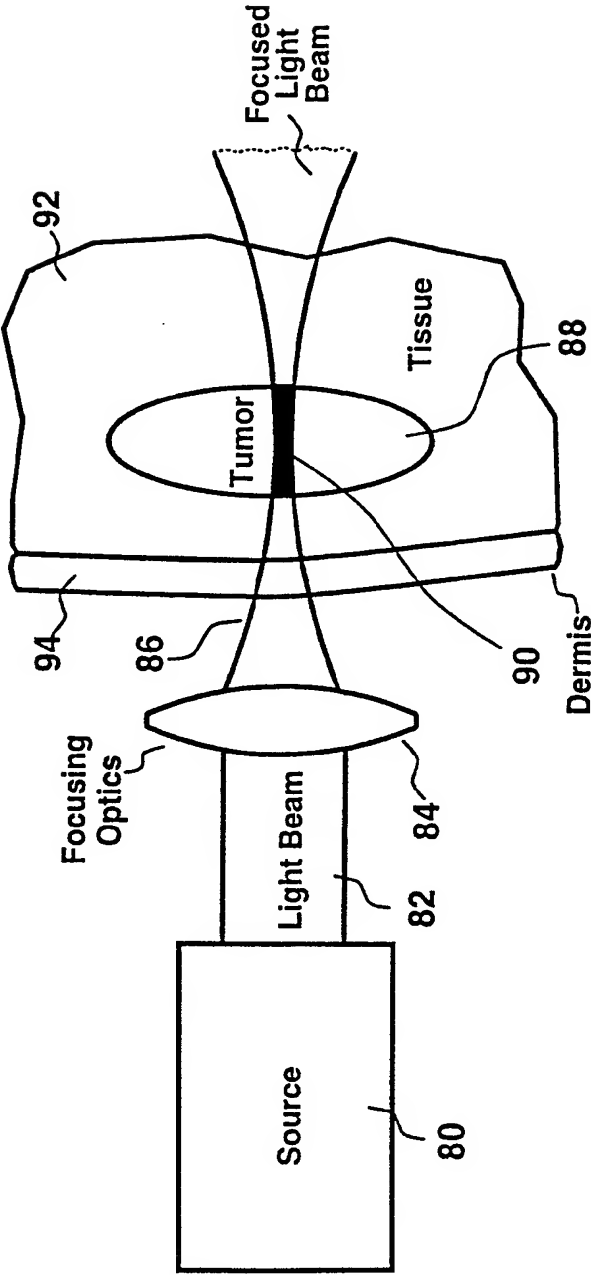
Fig. 3.



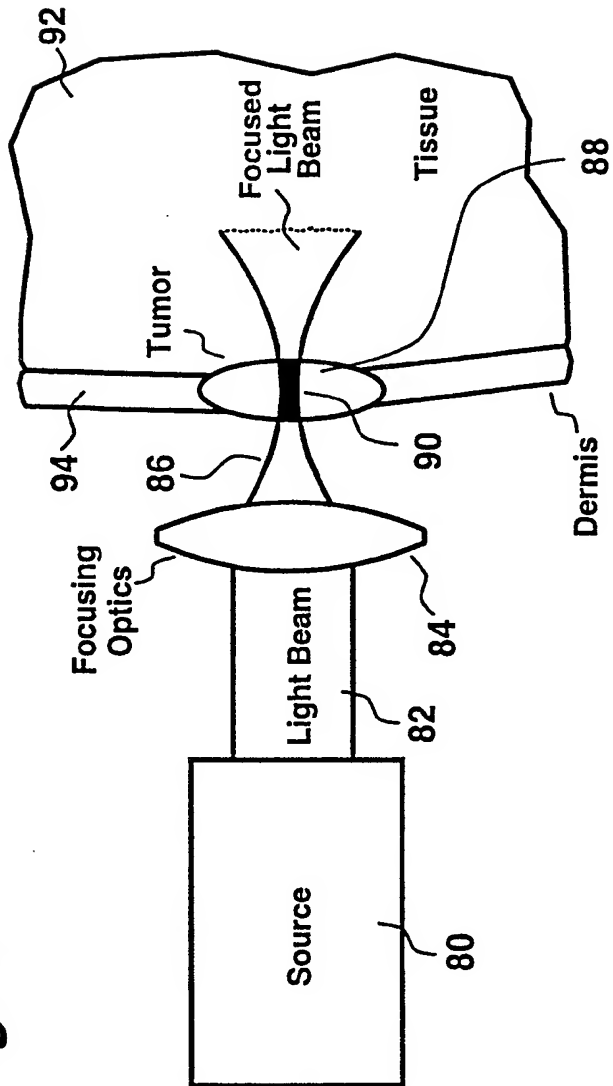
**Fig. 4.**



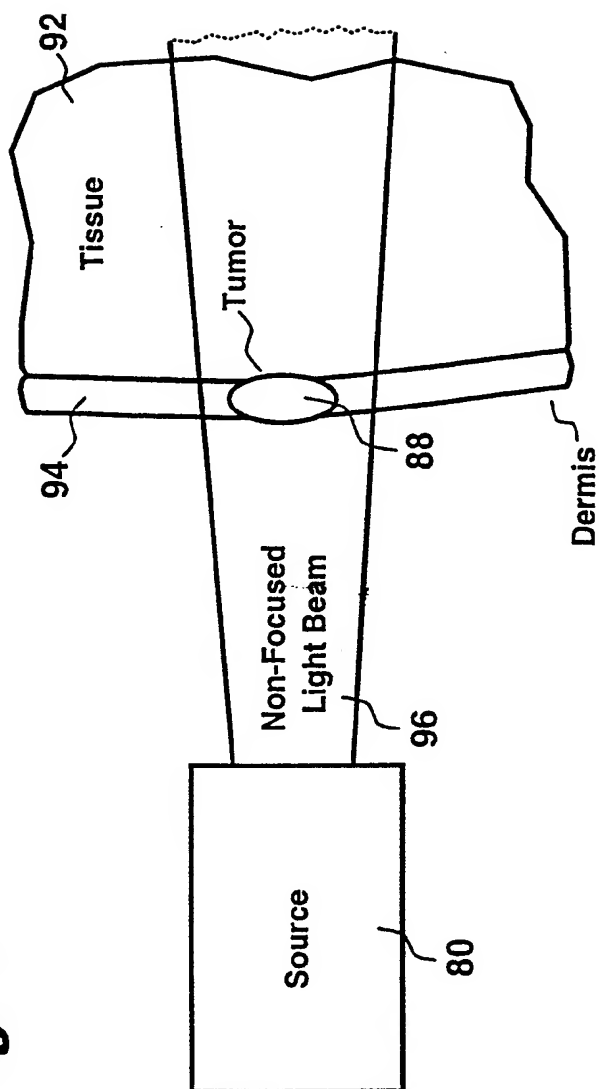
**Fig. 5.**

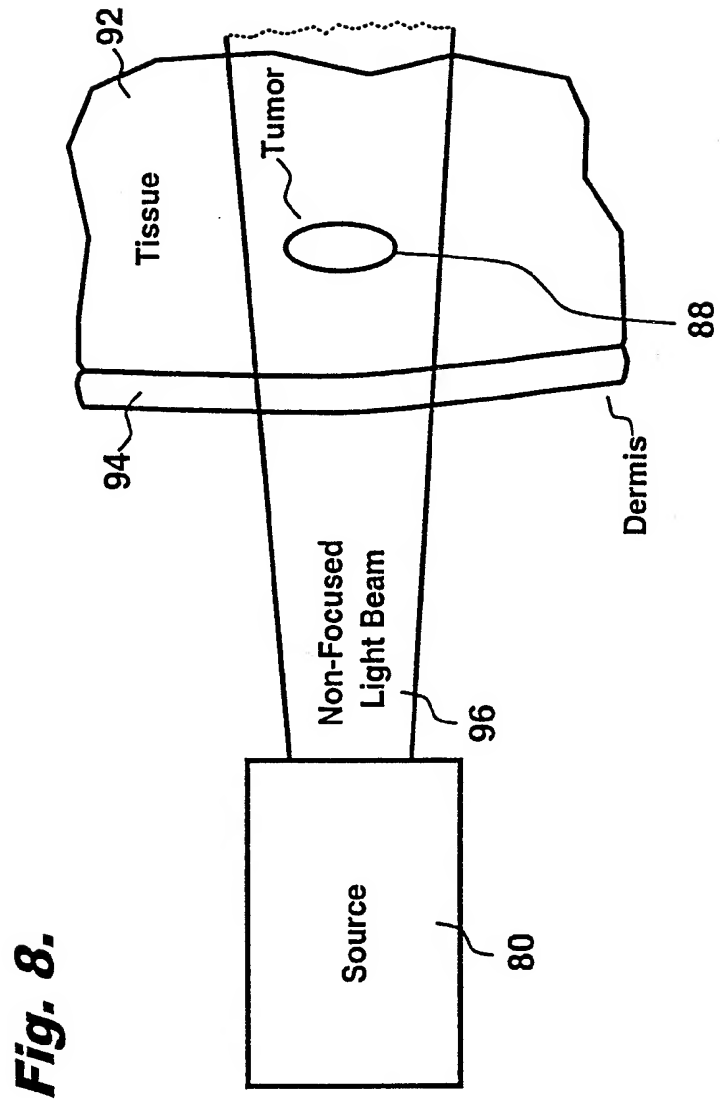


**Fig. 6.**



**Fig. 7.**





**Fig. 9.**

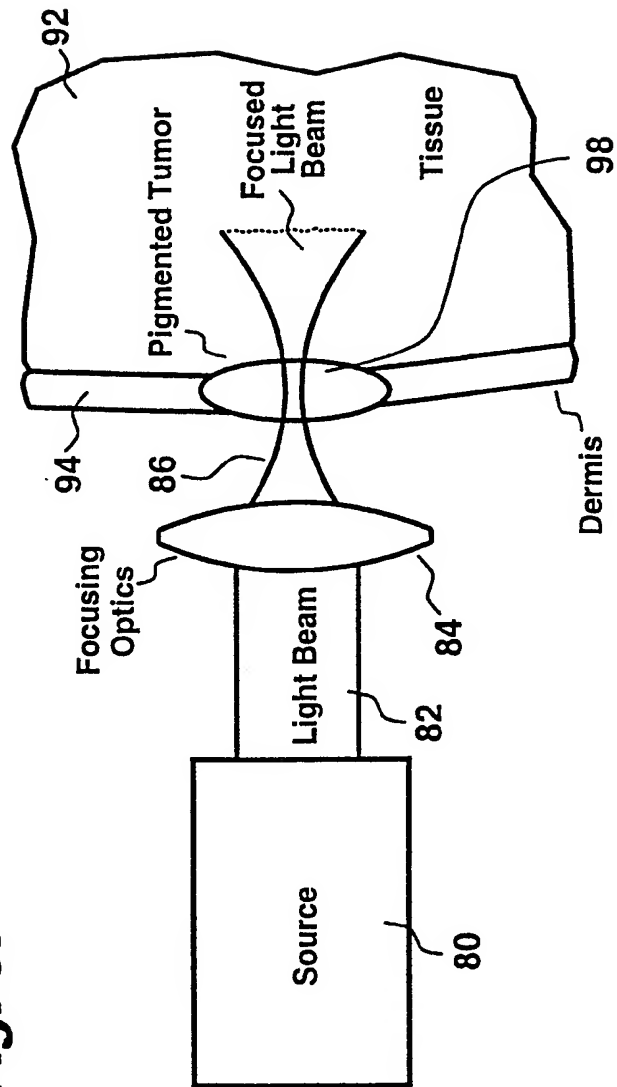
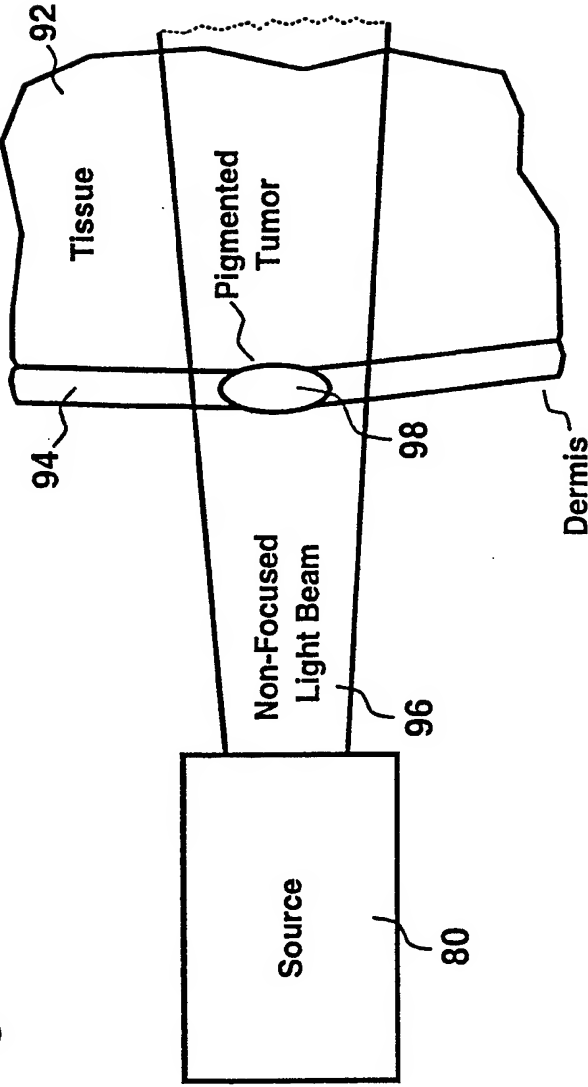




Fig. 10.



# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US99/17176

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61B 19/00

US CL :128/898

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/898; 250/458.1; 604/20; 606/9; 607/2, 3, 89

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WEST, EAST, MEDLINE, APS

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 5,829, 448 A (FISHER et al.) 03 November 1998, entire document.	1-110
A	US 4,822,335 A (KAWAI et al.) 18 April 1989, entire document.	78-96, 108-110
A	US 5,034,613 A (DENK et al.) 23 July 1991, entire document.	19-36, 78-96, 98, 102-104, 108-110
A	STABLES et al., Photodynamic therapy, Antitumour Treatment, Cancer Treatment Reviews (1995) 21, pages 311-323.	1-77, 97-107

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search  
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International application No.

PCT/US99/17176

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KATSUMI et al., Photodynamic Therapy with a Diode Laser for Implanted Fibrosarcoma in Mice Employing Mono-L-Aspartyl Chlorin E6 , Research Note, Photochemistry and Photobiology, 1996. 64(4), pages 671-675.	1-110

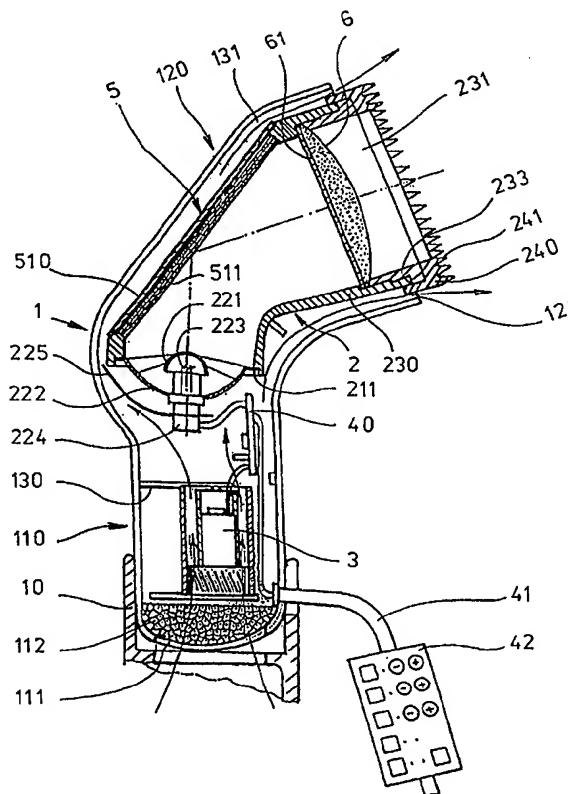


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification 7 :</b> <b>A61N 5/073, A61H 23/02, F21V 9/14</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/30714</b> <b>(43) International Publication Date:</b> 2 June 2000 (02.06.00)
<b>(21) International Application Number:</b> PCT/CZ99/00044 <b>(22) International Filing Date:</b> 24 November 1999 (24.11.99) <b>(30) Priority Data:</b> PV 3823-98 24 November 1998 (24.11.98) CZ PUV 10058-99 9 November 1999 (09.11.99) CZ <b>(71)(72) Applicant and Inventor:</b> VOVES, Vladimir [CZ/CZ]; Lukavec 268, 395 26 Lukavec (CZ). <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> PICKA, Pavel [CZ/CZ]; Myslikova 70, 395 01 Pacov (CZ). <b>(74) Agent:</b> FISCHER, Michael; Na Hrobci 5, 128 00 Praha 2 (CZ).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> <i>In English translation (filed in Czech).</i>

**(54) Title:** INSTRUMENT FOR LIGHT THERAPY**(57) Abstract**

The instrument for light therapy consists of an outer casing (1) with a front section (120) terminated with the first hole (121), in which inner casing (2) with a light source (223), reflector (221, 222) and Brewster polariser (5) consisting of a system parallel glass plates (511) lying on each other are located, while the output section (230) of the inner casing (2) reaching as far as the first hole (121) of the outer casing (1) holds a light filter (112), and with a rear section (110) that changes into the second hole (111), in which fan (3) for generation of pressure difference between both holes (121, 111) is located, whereas the system of glass plates (511) of Brewster polariser (5) consists of drawn glass plates (511) with surface irregularities defining cavities (512) of unequal shape between plates (511). A massage ring (240) is allocated to the Brewster polariser, that is located in output section (230) of inner casing (2) and/or at the end of front part (120) of outer casing (1).



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## Instrument for Light Therapy

Description

The invention concerns an instrument for light therapy, consisting of an outer casing with a front section terminated with the first hole, in which inner casing with a light source, reflector and Brewster polariser consisting of a system parallel glass plates lying on each other are located, while the output section of the inner casing reaching as far as the first hole of the outer casing holds a light filter, and with a rear section that changes into the second hole, in which fan for generation of pressure difference between both holes is located.

Instruments for light therapy are used to support biological processes by means of effects of linear-polarised light. Action of the linear-polarised light increases cell activity and supports healing processes of various disturbances of body surface such as wounds, furuncles and various disturbances of epithelium. In the publication DE 3220218 an equipment and a method are described for a stimulation of biological processes and for activating cells by means of linear-polarised light. The Brewster polariser consists of a larger number of plane-parallel glass plates from common transparent glass inclined under the known Brewster angle, e.g. four glass plates with a double number of reflection planes that reflect about 35% of incident light. The Brewster polariser is placed in a cylindrical cabinet with the same diameter as the reflector and lens body. The cylindrical cabinet is cut in the axis with an inclined plane and glass plates are inserted into the ellipse-shaped cross-

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section. Rays pass through under an obtuse angle that corresponds to the double of the Brewster angle. The linear-polarised light has continuous or seemingly continuous distribution of spectrum in the usable direction. Despite the indisputable healing effects, the bundle of rays generated by the light source generates too much heat at higher power output that in case of the current configuration cannot be satisfactorily removed by means of air from fan. Another disadvantage of this appliance is a complicated construction of the optical equipment. The publication WO 96/04958 describes a healing lamp with a Brewster polariser formed by several drawn glass plates lying directly one on the other. These glass plates provide better heat removal thanks to a close contact of glass plates and thanks to cooling air passing through a narrow gap between the casing jacket and system of glass plates of the Brewster polariser. Because the light space with reflector, light source, glass plates of the Brewster polariser and output filter is separated from the space, through which air passes, and because flowing air has no access between glass plates of the Brewster polariser, the polariser is not polluted with dust. The cooling air passes through the casing of the instrument and leaves the casing in a different direction than to the cured area. The disadvantage of this configuration is a complicated manufacture of the whole instrument, low efficiency of light reflection and impossibility to use the airflow to support the instrument's healing effect. The publication DE 3733905 describes a healing lamp with linear-polarised light. With this lamp, the reflector with a light source generates a bundle of rays that impinges on the Brewster polariser made of a larger number of plane-parallel glass plates configured next to each other at small determined distances. Glass plates are enclosed in a

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metal plate, whose outer surface is fitted with cooling fins as well as the outer surface of the reflector. The healing lamp consists of two tubular casings that make an angle that corresponds to the Brewster angle. The Brewster polariser is located in the cranked section. The straight section is tightly closed by means of a filtration insert. The disadvantage of the above-described healing lamp is its robust construction necessary to achieve a satisfactory light performance. Documentation EP 0137005 describes a healing illumination instrument consisting of a crank-shaped cylindrical casing, whose cranked section accommodates the Brewster polariser plates. One of the straight sections of the casing holds a light source with reflector, which transmits a bundle of rays onto the Brewster polariser plates. The bundle of rays reflects from these plates into the second straight section of the casing and the light beam leaves the instrument at the output hole of the second straight section. This hole is arranged around an optical appliance, which can be, for example, an optical filter. A fan is located after the reflector in the first straight section of the casing. This fan causes air to be sucked from the output hole area into the second straight section, the air passes through the cranked section of the cylindrical casing and a peripheral gap along the reflector into the fan that forces the air out from the casing through holes in the facing wall of the first straight section. The fan can be set to the opposite direction of airflow, in which case the air is sucked in through holes in the facing wall of the first straight section, passes through the fan and is pushed through an annular gap between the reflector and casing. Then the air flows along the top plate of the Brewster polariser and after changing the direction in the cranked section of the casing, the air flows through the



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second straight section through annular holes along the optical equipment out of the instrument. In case of the latter direction of flow, the air flows to the healed area and around. However, disadvantage of this instrument is that in case of this direction, the air flows directly along the top plate of the Brewster polariser and hits the optical equipment located in the output hole of the second section and pollutes it with dust. Documentation WO 96/04959 describes a healing lamp for generation of linear-polarised light that consists of an outer casing with a shape of cranked cylinder with holes on both sides, and of an inner casing located inside the outer casing. The inner casing also has a shape of a cranked cylinder. One end of the inner casing is fitted with a reflector with a light source transmitting a bundle of rays onto plates of the Brewster polariser located at the area of cranking of the cylindrical shape of the inner casing. The bundle reflects from the plates of the Brewster polariser and leaves the instrument through the output hole in the output section of the inner casing that terminates at the area of the outer casing output hole. An annular gap is formed between the output section of the inner casing and the first input hole of the outer casing. The fan located in the area of the second output hole of the outer casing sucks air that passes through this gap into the inner area of the outer casing. The fan forces the sucked air out of the outer casing through the second output hole. The air flows in the direction from the healed area, through the annular gap between the output section of the inner casing and the first output hole of the outer casing along the reflector and further along the inner electrical wiring into the fan and from the fan through the hole in the outer casing into the environment, which seems to be disadvantageous, because the flowing air is not utilised to

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increase the healing effects. The sucked air simultaneously carries a mass of biological contamination from the healed area into the annular gap between the output section of the inner casing and the first input hole of the outer casing. This biological contamination is undesirably deposited on the inner wiring of the instrument. This effect is undesirable, because this is a biological contamination, which is a source of various infections. Disadvantage of this healing lamp according to the above description also is a limited light performance and a limited healing effect. The limited light performance and healing effect are caused by low efficiency of light reflection on the Brewster polariser. The Brewster polariser according to the above description consists of several layers of drawn glass plates arranged directly on top of each other. Purchase costs of floated glass plates are high. The reflection efficiency of bundle of rays on the above glass plates is low and therefore also the light performance of the bundle of rays, that flows out from the output hole of the output section of the inner casing onto the healed area, is low. The low reflection efficiency of the light bundle on the glass plates of the Brewster polariser is caused by quality of the surface of drawn glass plates, because during production at temperatures in the glass production equipment, the drawn glass plates are placed or transported on guide plates made of zinc. At high temperatures of plates, zinc penetrates into the surface of the processed plates. Even the slightest content of zinc in the surface layer causes aggravation of the reflection capacity. The same effect also appears during the production of glass plates in every other method of production, in which guide plates have to be used, that with the current state of technology are exclusively made to contain zinc. Finally, documentation CZ 8371 describes a

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Brewster polariser that consists of a system of at least two adjoining glass reflection plates, where at least one black spacing insert is adjoining to one of its sides. The system of glass plates is inserted into the hole in the casing and locked together with the black spacing insert. Use of one black spacing insert cannot always comply with various manufacturing tolerances of glass reflection plates and their thermal expansion during operation of the instrument. This also causes a play between the glass reflection plates, which requires other black spacing inserts of different thickness to be used. The aim of the invention is to eliminate the disadvantage of the current state of the art and to provide an instrument for light therapy that has a higher light performance at the output, lower power consumption, generates less heat, is more hygienic and does not clog with contamination, does not clog optical equipment located at the output with contamination, enables improvement of existing healing effects and expansion of functions with massage effects, features a simple construction, can be handled more easily and features the same or lower demands and costs during production and assembly.

Disadvantages of the state of the art considerably eliminates and the aim of the invention meets an instrument for light therapy consisting of an outer casing with a front section terminated with the first hole, in which inner casing with a light source, reflector and Brewster polariser consisting of a system parallel glass plates lying on each other are located, while the output section of the inner casing reaching as far as the first hole of the outer casing holds a light filter, and with a rear section that changes into the second hole, in which fan for generation of pressure difference between both holes is located according to the

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invention consisting in that the system of glass plates of Brewster polariser is created by drawn glass plates with surface irregularities defining cavities of unequal shape between plates.

According to advantageous executions of the invention the outer side of the system of glass plates can be provided with insert with black surface that has profile patterns on the side of glass plates, massage ring can be allocated to the Brewster polariser, that is located in output section of inner casing and/or at the end of front part of outer casing. With advantage the massage ring can be provided with flexible massage elements, advantageously can be the massage ring provided with for generating a magnetic field outside the output hole of inner casing. Magnets can have with advantage a permanent or an electrical excitation. With advantage the massage ring can be a movable part of vibrator located at output section of inner casing and/or at the end of front section of outer casing. According to an advantageous execution there is fan allocated to Brewster polariser whereas this fan is set for airflow direction from the second hole of outer casing toward its first hole. With advantage there is lens allocated to Brewster polariser, which is located in output section of inner casing to focus rays reflected from the system of glass plates into the focus located outside outer casing on the optical axis of lens.

The construction is advantageous for improvement of the degree of utilisation of the reflected bundle of rays. In this construction, the elliptic reflector section is located against the parabolic reflector section so that optical axes of both reflector sections merge into a single optical axis. The light source is located in the primary focus of the elliptic reflector section, whose secondary focus is basically

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identical with that of the parabolic reflector section and the size of the elliptic reflector section is considerably smaller than that of the parabolic reflector. This system of reflectors, in fact, avoids diffuse light. With respect to simplification of production and reduction of requirements on accuracy of production of glass reflection plates, it is advantageous to use a construction, in which the Brewster polariser consists of three glass reflection plates that as a result of various surface irregularities create unequal gaps between each other and are terminated at least with one black spacing insert and are jointly inserted into the hole in the casing and locked by means of the carrier together with the black spacing insert. To enable simple amplification or attenuation of irradiation intensity or to regulate the size of the illuminated area, it is an advantage that the lens consists of a spherical convergent lens, whose focus lies on the optical axis in front of the cabinet in the direction of the outgoing light. The construction is also advantageous for improvement and intensification of programmable healing, irradiation and massage effects. According to this construction, a massage head is detachably fitted to the holder end. At its front part, this head is provided with flexible massage elements and is manually and/or electrically controlled. Circling motion of the massage head with flexible elements over the skin surface improves blood circulation in the skin and together with exhaustion of warm air it considerably improves the healing irradiation effects and adds also massage effects. Electrical control of the massage head, e.g. with vibrations, is another improvement of the instrument's function that enhances its utilisation in medicine and cosmetics. The vibration intensity and cycle length of the selected program can be remote controlled and changed by means

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of program buttons and buttons for amplification and attenuation of effects. Holder supports, air deflector for guiding air supplied by fan to cool the light source and Brewster polarised located within the cabinet are advantageous for amplification of the cooling effect. In order to keep cleanliness of the sucked air on the airtight construction of the optical equipment for guiding, polarisation and filtration of light, it is an advantage that air access holes are covered with a replaceable air filter, which helps to prevent contamination of the treated body surface areas. Further, it is advantageous to use the construction, in which the light filter has a colour shade that enables filtration of undesired light spectrum components. For use at rehabilitation centres when healing post-fracture, operation and burn states, the handling of the instrument is simplified so that the electrical outfit for the radiated light is fitted with a controller of program of healing, irradiation and massage functions controlled by means of program buttons and buttons for amplification and attenuation of effects with light and/or acoustic indication. This enables treatments to be performed at outpatient clinics and at beds without any undesired side effects. This is achieved by means of construction of the cabinet, enhanced construction of the Brewster polariser including simplification of glass reflection plates of the massage head and by means of introduction of remote control featuring a simple operation. The black spacing insert has a profiled surface that performs a function of a spring and flexibly compensates effects of manufacturing tolerances of thickness and thermal expansion of the system of glass reflection plates so that their tight seating onto each other in the hole of the inner casing after assembly is permanently guaranteed. Simple designation of the product and manufacturer

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is facilitated by the fact that the surface of the black spacing insert holds a marking, e.g. a trademark that is visible when looking into the instrument for light therapy against the direction of the outgoing polarised light. Thanks to the higher efficiency, the instrument for light therapy according to the invention has a considerably higher light performance at the output and thus lower power consumption and generates less heat at the outer side of glass plates of the Brewster polariser, it is more hygienic and does not clog with contamination, does not contaminate optical equipment located at the output with dust, thanks to devices allocated to the Brewster polariser it enables improvement of existing healing effects and expansion of functions with mechanical, magnetic and optical massage effects, it features a simple construction, is easy to handle and features the same or lower demands and costs during production and assembly.

The invention is explained in details by means of drawings. Figure 1 shows a longitudinal sectional view of the instrument for light therapy according to the invention. Figure 2 shows a detail of a longitudinal sectional view of glass plates of the Brewster polariser. Figure 3 shows a view of output section of the inner casing. Figure 4 shows a longitudinal sectional view of the massage ring with flexible massage elements. Figure 5 shows a longitudinal sectional view of the massage ring with permanent magnets and electromagnets. Figure 6 shows a longitudinal sectional view of massage ring consisting of a vibrator. Figure 7 shows an example of light path of bundle of rays.

According to Fig. 1, the instrument for light therapy consists of an outer casing 1 made of plastic. It is an advantage, that this casing is divided into two sections longitudinally connected either with screws or by means of

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latches and clamps. In the longitudinal sectional view, the outer casing 1 is shown as a double contour line. Basically, the outer casing 1 has a shape of a cranked cylinder with front section 120 and rear section 110. Fins not shown in the figure hold the inner casing 2 in the front section 120. This casing also has the shape of cranked cylinder. The outer side of the cranked section holds Brewster polariser 5 consisting of a system of drawn glass plates 511 attached to bearing plate 510 fitted into inner casing 2. Inner casing 2 is provided with hole 211 at one of its end. Shoulder of the hole holds reflector 222 that focuses rays generated by light source 233 fitted within reflector 222 by means of socket 224 and partly covered by known method with the other reflector 221. The other end of inner casing 2 changes into output section 230 with output hole 231. The recess (not show in the figure) of output section 230 of inner casing 2 holds filter 61 and lens 6 is located outside filter 61. Filter 61 and lens 6 are fixed in output section 230 of inner casing 2 by means of annular ring 233 of a suitable shape. Annular ring 233 holds massage ring 240 fitted with massage elements 241. It is an advantage that massage elements 241 can be made of a flexible material so that contact with the treated area does not cause irritation, but a desirable massage. Front section 120 of outer casing 1 changes into the rear section 110 either gradually or in the form of a crank. This rear section 110 holds fan 3 fitted in the outer casing, for example, by means of internal ribs 130. Rear section 110 of outer casing 1 is terminated with hole 111 in front of which air filter 112 is fitted. Supply cable 41 leading to switchboard 40 is taken from controller 42 to rear section 110 of outer casing 1. Cables are distributed from here to socket 224 of light source 223 and to fan 3. With its rear section 110, the instrument



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for light therapy can be seated in holder 10. Fan intakes air through hole 111, the air then passes through air filter 112, along blades of fan 3 and then it goes toward reflector 222 of light source 223. Socket 224 of light source 223 holds air deflector 225 that directs the airflow in the area of reflector 222 and brings the air into annular gap 131 between inner casing 2 and front section 120 of outer casing 1. Air passes through this gap 131 along Brewster polariser 5 and along output section 230 of inner casing 2 into the first hole 121 of front section 120 of outer casing 1 and out of the instrument through the first hole 121 in the direction to the treated area along massage ring 240. Light rays generated by light source 223 impinge on mirror surface of reflector 223 from which the rays are directed in a bundle to the surface of glass plates 511 of Brewster polariser 5, from which the rays are reflected under the known Brewster angle and being linear-polarised, they pass through filter 61. It is an advantage, that lens 6 is located behind filter 61 in the direction of rays. This lens focuses rays into the focus located on the optical axis of lens 6 outside of inner casing 2. According to Figure 2, drawn glass plates 511 are connected into a system, in which they are close to each other. Glass plates 511 manufactured by means of the draw technology have irregularities on their surfaces. Thickness of these irregularities can vary, but according to experience, it is advantageous the thickness to be about 1 mm. Due to air humidity, the plates are not self-sticky. There is zero mutual distance at contact points of adjacent glass plates 511 and the distance can vary in the cavity areas. Glass plates 511 have cavities 512 of various sizes between them, for example only microscopic ones that enable a different refraction of light. When the bundle of rays impinges on the first drawn

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glass plate 511, considerable part of rays is reflected under the Brewster angle. Part of the rays pass through the drawn glass plate 511 and cavities 512 of various sizes and impinge on the second of glass plates 511 under a changed angle as a result of light refraction index and depending on the thickness of glass plate 511 and cavity 512. Part of these rays is reflected back under the angle of incidence and part of the rays pass again through the drawn glass plate 511. This physical phenomenon repeats on every next glass plate 511 and terminates on black insert 520 with profiles on surface 521 that is bound on the last drawn glass plate 511. Drawn glass plates 511 can also have a different thickness. The optimum polarisation effect is achieved by means of a suitable combination of drawn glass plates 511. This increases efficiency of the Brewster polariser while considerably decreasing production costs on manufacture of drawn glass plates 511. Black insert 520 is seated on bearing plate 510 inserted into the recess in the hole of inner casing 2. Thanks to profiles of surface 521, black insert 521 is flexible and thus suitably compensates production tolerances and thermal expansion of the system of assembled drawn glass plates 511 so that they are permanently in close contact with each other. The profiled surface 521 of black plate 520 also enables the product to be marked in a simple way. A suitable shape of the recess formed in the profiled surface 521 can be used to mark instructions for use or manufacturer's trademark etc., because the profiled surface 521 is visible during operation of the instrument when viewed in the direction against the outgoing polarised light. Figure 3 shows the front section 120 of outer casing 1, from which collar 233 of output section 230 not shown in the figure is protruding from the first section 121. According to Figure 4, the simple implementation of massage

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ring 240 is provided with flexible massage elements 241. According to Figure 5, permanent magnets 242 or electromagnets 243 connected with electrical socket 247 for connection to a power supply source are located in the body of massage ring 240. According to Figure 6, it is an advantage, that massage ring 240 is a movable component of vibrator 248. Vibrator 248 consists of collar 234 as a fixed component embedded in output section 230 of inner casing 2 and/or hole 121 of outer casing 1, further as an example, it consists of flexible attachment 246, massage ring 240 that forms the movable component and tools for generating oscillating motions of massage ring 240 that, as an example, consist of electromagnets 243 connected with electric terminal 247 for connection to electrical power supply. The shown flexible attachment 246 is only as an example and can also be replaced with push-type attachment of massage ring 240 in collar 234 for oscillating motions either in axial direction or for rotary-oscillating motions along the axis of massage ring 240. When implementing massage ring 240, together with light effects it is also possible to perform massage of surface of the treated area. Circling or oscillating motions of the instrument, when the instrument is manual-controlled utilise the advantage of flexible massage elements 241. It is an advantage, that the manual control can be substituted with a vibrator as mentioned above. It is an advantage, that programmable functions of controller 42 can be utilised, which enable programmable amplification and attenuation of vibrations, light flow, flow speed and temperature of the airflow. Exhausting of warm air onto the treated area is also important for the healing effect, namely because warm air according of the invention is exhausted outside the circle formed by massage ring 240. According to the advantageous implementation of the instrument for light

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therapy according to Figure 7, reflector 222 has a parabolic reflection plane 252. Another elliptic reflector 221 with elliptic reflection plane 251 is situated against the parabolic reflector 222 so that optical axes 501 and 502 are identical. Light source 223 is located in primary focus F1 of part of elliptic reflector 221 and whose secondary focus is identical with focus F2 of parabolic reflector 222, i.e. with the focus of parts of parabolic reflector 222, if the reflector is divided into several parts. Reflection plane 251 of elliptic reflector 221 is considerably smaller than reflection plane 252 of parabolic reflector 222. Such configuration considerably restricts diffusion of light radiated by light source 223. It is an advantage, that after passing through filter 61, the bundle of rays reflected from the Brewster polariser is focused by lens 6 into focus F3 located on optical axis 503 outside the outer casing that is not shown. The instrument for light therapy can be used not only for stimulation of biological processes when healing surface wounds on bodies, but also in other branches of medicine, cosmetics and biology. It can be used in physical treatment in the branch of mouth, jaw and face surgery.

Patent claims

1. The instrument for light therapy, consisting of an outer casing with a front section terminated with the first hole, in which inner casing with a light source, reflector and Brewster polariser consisting of a system parallel glass plates lying on each other are located, while the output section of the inner casing reaching as far as the first hole of the outer casing holds a light filter, and with a rear section that changes into the second hole, in which fan for generation of pressure difference between both holes is located,

c o n s i s t i n g   i n   t h a t  
the system of glass plates of Brewster polariser (5) consists of drawn glass plates (511) with surface irregularities defining cavities (512) of unequal shape between plates (511).

2. Instrument for light therapy according to claim 1,  
c o n s i s t i n g   i n   t h a t  
the outer side of the system of glass plates (511) is provided with insert (520) with black surface that has profile patterns on the side of glass plates (511).

3. Instrument for light therapy according to claim 1,  
c o n s i s t i n g   i n   t h a t  
massage ring (240) is allocated to the Brewster polariser, that is located in output section (230) of inner casing (2) and/or at the end of front part (120) of outer casing (1).

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4. Instrument for light therapy according to claim 3, consisting in that massage ring (240) is provided with flexible massage elements (241).

5. Instrument for light therapy according to claim 3, consisting in that massage ring (240) is provided with magnets (242, 243) for generating a magnetic field outside the output hole (231) of inner casing (2).

6. Instrument for light therapy according to claim 5, consisting in that magnets (242, 243) are permanent or with electrical excitation.

7. Instrument for light therapy according to claim 4, consisting in that massage ring (240) is a movable part of vibrator (248) located at output section (230) of inner casing (2) and/or at the end of front section (120) of outer casing (1).

8. Instrument for light therapy according to claim 1 - 7, consisting in that there is fan (3) allocated to Brewster polariser (5). This fan is set for airflow direction from the second hole (111) of outer casing (1) toward its first hole (121).

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9. Instrument for light therapy according to claim 1,  
c o n s i s t i n g   i n   t h a t  
there is lens (6) allocated to Brewster polariser (5), which  
is located in output section (230) of inner casing (2) to  
focus rays reflected from the system of glass plates (511) into  
the focus located outside outer casing (2) on the optical axis  
of lens (6).

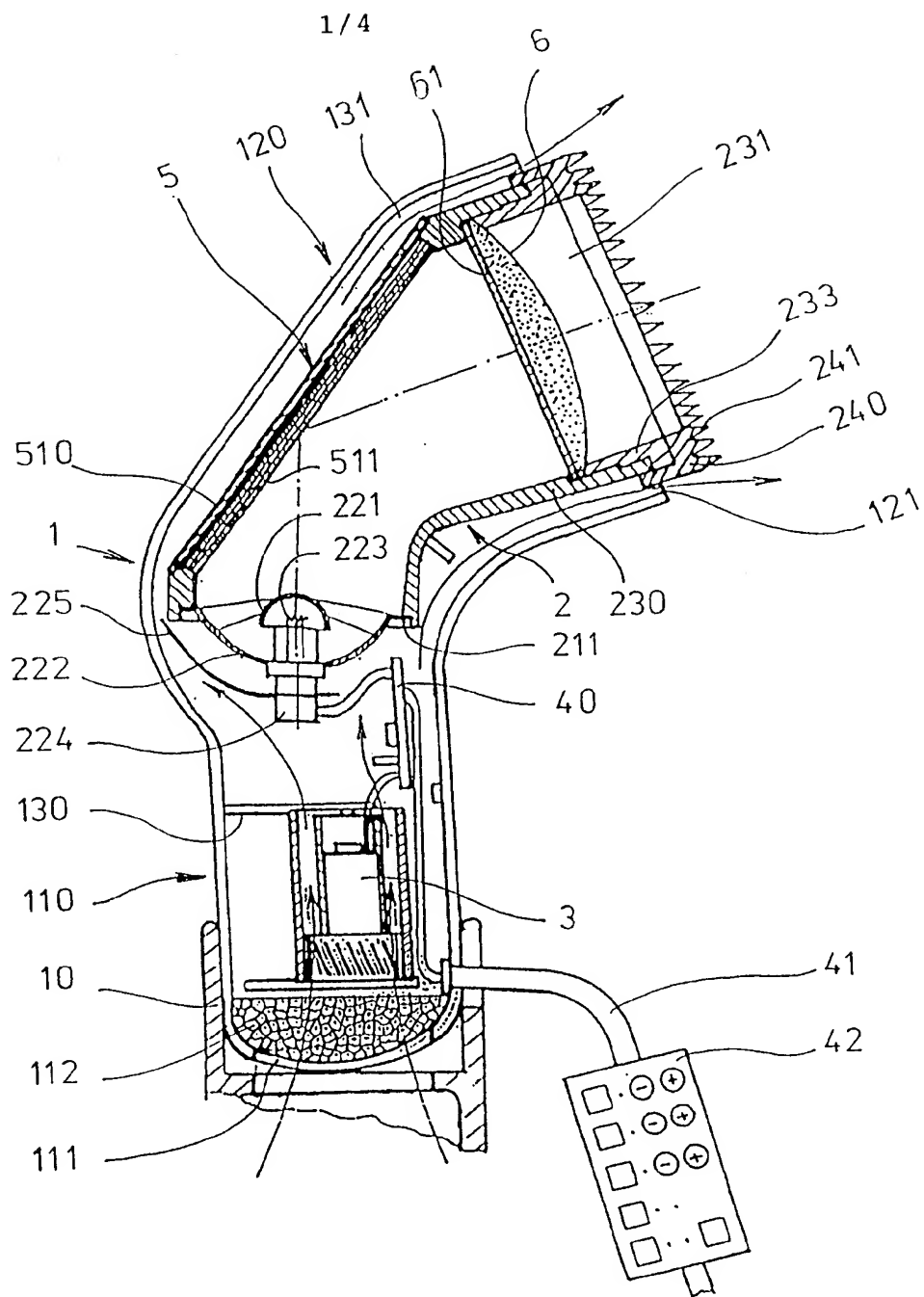


Fig. 1



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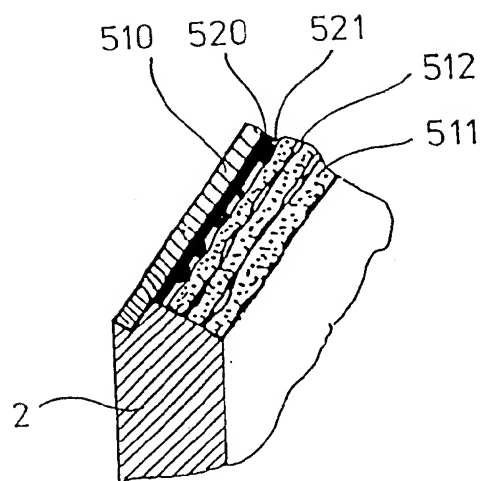


Fig. 2

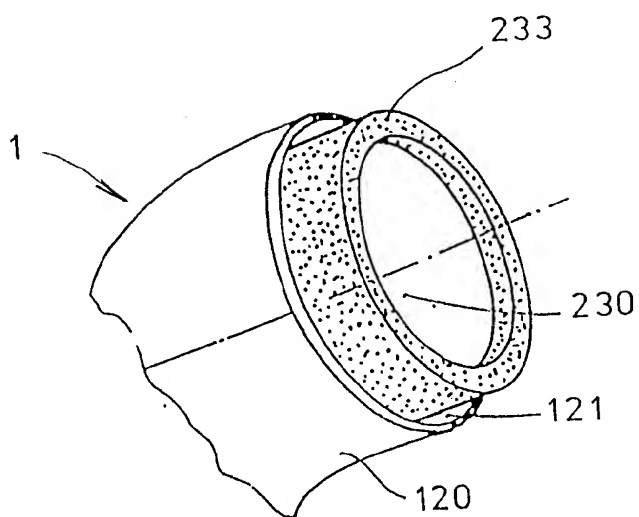


Fig. 3

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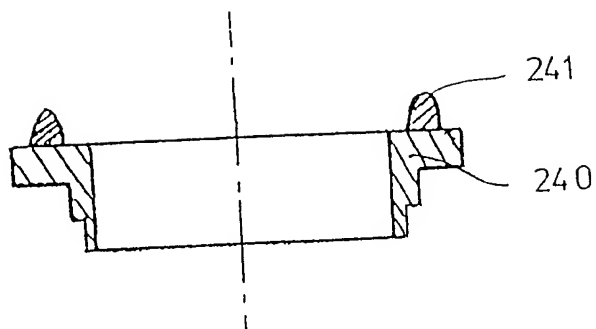


Fig. 4

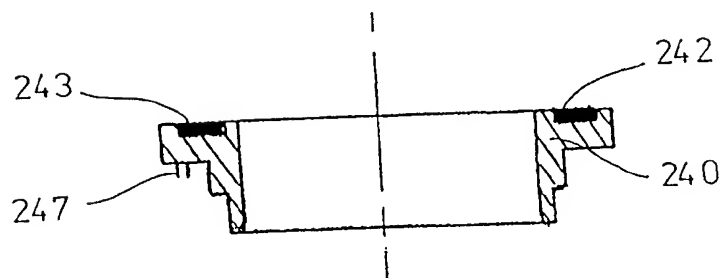


Fig. 5

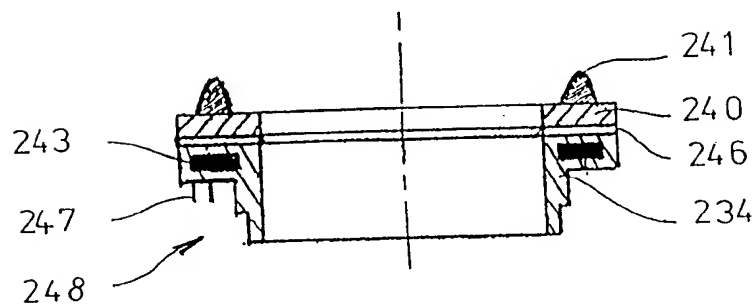


Fig. 6

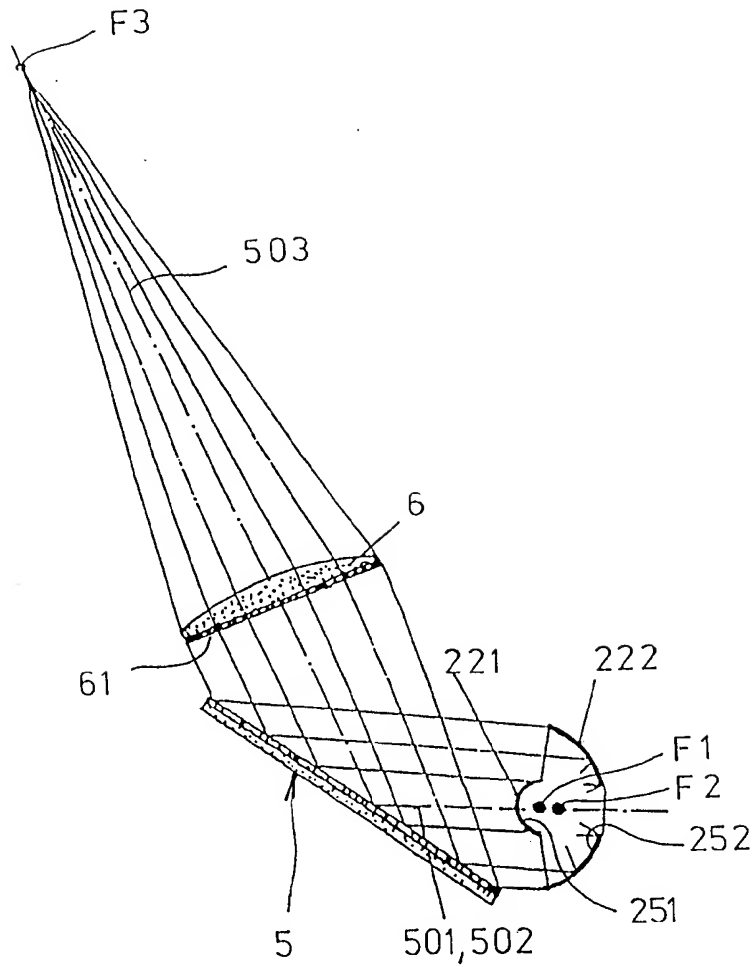


Fig. 7

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/CZ 99/00044

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61N5/073 A61H23/02 F21V9/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61N A61H F21V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 0 137 005 A (AMS AUTOMAT MESS & STEUERTECH) 17 April 1985 (1985-04-17) cited in the application page 5, line 26 -page 8, line 16	1
A	WO 96 04958 A (BIOPTON AG ;BOLLETER HEINZ (CH)) 22 February 1996 (1996-02-22) cited in the application page 4, line 15 -page 8, line 15	1
A	WO 96 04959 A (BIOPTON AG ;BOLLETER HEINZ (CH)) 22 February 1996 (1996-02-22) cited in the application page 4, line 3 -page 8, line 23	1
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search

22 March 2000

Date of mailing of the international search report

30/03/2000

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# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/CZ 99/00044

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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information on patent family members

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information on patent family members

International Application No

PCT/CZ 99/00044

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## PROCESS AND APPARATUS FOR THE COSMETIC TREATMENT OF ACNE VULGARIS

This invention discloses a process for the cosmetic treatment of acne vulgaris by irradiation of the affected skin areas with light and an apparatus for the application of the process.

A known process uses UV light for the irradiation of the face. This, however, has the possible disadvantage of erythema formation or an undesirable oxidation of skin pigments.

Also known is a treatment with a cream containing approximately 0,5 % benzoyl peroxide. The disadvantage of this treatment is possible skin dryness.

It is an object of the present invention to provide a process and an apparatus for the treatment of acne which not only eliminates the known disadvantages but also results in an excellent cosmetic effect.

This task is accomplished in accordance with the invention by applying light from low pressure mercury discharge (fluorescent) lamps having two different spectra, one in the blue range from 400 to 450 nm, the other in the red range from 580 to 659 nm.

Irradiation in accordance with the invention does not result in UV damage to the skin nor in significant skin dryness.

Both partial spectra in accordance with the invention are additive. The resulting spectrum is adapted to the action spectrum for the inactivation of the propionibacterium acne. It has a biostimulating effect on the skin cells. This is caused by the fact that propionibacterium acne produces porphyrins which may be excited by short wavelength light. This has a lethal effect on the bacteria.

Light exposure studies were conducted with 61 patients having mild to moderate acne. They were treated with blue-red light in accordance with the invention and with blue light. The results were compared with white light exposure and treatment with benzoyl peroxide cream.

Patients were instructed to use the lamps for 15 minutes each day or apply the benzoyl peroxide cream twice daily.

Patient assessment was conducted every four weeks. The results are shown in the following table:

Observation	Blue / Red Light		Blue Light		White Light		Cream	
	Doctor %	Patient %	Doctor %	Patient %	Doctor %	Patient %	Doctor %	Patient %
worse/ unchanged	27	27	25	50	46	46	19	19
slight/moderate improvement	18	27	42	33	46	46	44	50
significant improvement	55	46	33	17	8	8	37	31

The number listed under "doctor" refers to a doctor's assessment, the number in the "patient" column is the patient's assessment after blue light or cream treatment.

Results show that the best results were obtained with mixed blue / red light in accordance with the invention with an average reduction of 66 % in inflammatory and 42 % in non-inflammatory lesions. With blue light the reduction was 50 % and 32 %, with white light 21 % and 0 % and with benzoyl peroxide cream 61 % and 58 %, respectively.

Investigators assessment showed a significant improvement, 55 % with blue / red light, 33 % with blue light, 21 % with white light and 37 % with cream treatment.

Patients assessment showed a significant improvement of 46 % with blue / red light, 16 % with blue light, 8 % with white light and 31 % after cream treatment. After light exposure dryness was negligible.

Fig. 1

shows the spectral energy distribution of a blue lamp,

Fig. 2

that of a red lamp according to the invention, and

Fig. 3

shows the action spectrum of the inactivation of propionibacterium acnes.

Fig. 4

shows an apparatus for the treatment of acne vulgaris, consisting of a rectangular housing 1, a time switch 4 and double-ended fluorescent lamps 5, 6, 7, 8.

Fig. 5

shows another embodiment of the apparatus shown in Fig. 4 with housing 2, timer switch 4, and single-ended fluorescent lamps 9, 10.

The apparatus as shown in Fig. 4 is provided with at least one blue and red lamp, each having a spectrum in accordance with Figs. 1 or 2, respectively. The lamps are of the double-ended low pressure mercury discharge (fluorescent) type, according to IEC Publication 60081. The embodiment in Fig. 4 shows four lamps 5, 6, 7, 8, arranged in parallel, having a bulb diameter of 15 to 40 mm and a length of 300 to 600 mm. Two of the lamps emit in the blue range, the other two in the red part of the spectrum. The arrangement of the lamps in the apparatus 1 is such that blue and red lamps alternate. In Fig. 4, lamps 5 and 7 have blue, lamps 6 and 8 red emission.

The embodiment of the apparatus in Fig. 5 shows two single-ended fluorescent lamps 9, 10, according to IEC Publication 60901. Each lamp consists of two legs 12, 13 and 14, 15, which are joined together by means of a hollow glass tube 11 located opposite the base end, or by a U-bent tube sealed to both legs at the end opposite the base. The total length of each lamp is between 225 to 414 mm, one leg of each lamp is coated with blue, the other leg with red phosphor in accordance with the invention.

To increase the irradiation efficiency, an external reflector is provided between each lamp and the housing 1, 2 such that the light is preferentially emitted in the forward direction. Alternatively, two or more lamps are provided with a common reflector. Still another alternative is to apply the reflector as a reflective coating onto the inner bulb wall of a lamp between the glass and phosphor coating as internal reflector.

Penetration depth of red light into the skin increases as from 600 nm up, depending also on the type of skin. Further, red light of longer wave lengths has a healing effect. To accommodate for this, variation of the intensity ratio of red to blue light can be advisable. Such accommodation in accordance with the invention can be effected by use of combinations of one blue with three red or one red with three blue lamps alternatively.

Each lamp can be operated on a dimmable ballast which allows for adjustment of the light intensity from 10 to 100 % of the nominal value.

Blue light and also red light in the 615 to 655 nm region have been found to have a killing effect on propionibacterium acne within certain exposure times and red/blue intensity ratios.

**Claims**

1.

Process for the cosmetic treatment of acne vulgaris by irradiation of the affected skin areas with light **characterized** by two emission spectra, one in the blue region (A) from 400 to 450 nm, the other in the red region (B) from 580 to 659 nm.

2.

Process according to claim 1, **characterized** in that the red region (B) is from 580 to 630 nm.

3.

Process according to claim 1, **characterized** in that that the red region (B) is from 630 nm to 658 nm.

4.

Process as defined in claim 1, 2 or 3 wherein the irradiation is conducted once per day for about 15 minutes.

5.

Apparatus for the application of the process in accordance with at least one of the preceding claims by means of a fixture (1, 2) having a housing (3) and dimmable ballast for each lamp, in which housing at least one lamp (5, 6, 7, 8, 9, 10) and at least one external reflector (16) between lamp and housing are arranged, and a timer clock for the limitation of exposure time.

6.

Apparatus according to claim 5, having four double-ended low pressure mercury vapor (fluorescent) lamps (5, 6, 7, 8) which are arranged essentially in parallel to each other, with a bulb diameter of 15 to 40 mm and a length of 300 to 600 mm of which two (5, 7) emit in the blue region and two (5, 8) in the red region.

7.

Apparatus according to claim 5 or 6, wherein the lamps are arranged such that blue (5, 7) and red (6, 8) lamps alternate.

8.

Apparatus according to claim 5 or 6 wherein one blue and three red emitting lamps are arranged.

9.

Apparatus according to claim 5 or 6 wherein one red and three blue emitting lamps are arranged.

10.

Apparatus according to claim 5 incorporating two single-ended low pressure mercury vapor (fluorescent) lamps according to IEC Publication 60901, having two legs which are joined together by means of a hollow glass tube (11) or by a U-bent tube sealed to both legs of each lamp, having a length of 225 to 414 mm.

11.

Apparatus according to claim 10, wherein one leg of each lamp emits in the blue region and the other leg in the red region of the spectrum.

12.

Apparatus according to claim 10 incorporating one lamp having two blue emitting legs and one lamp having a blue and a red emitting leg.



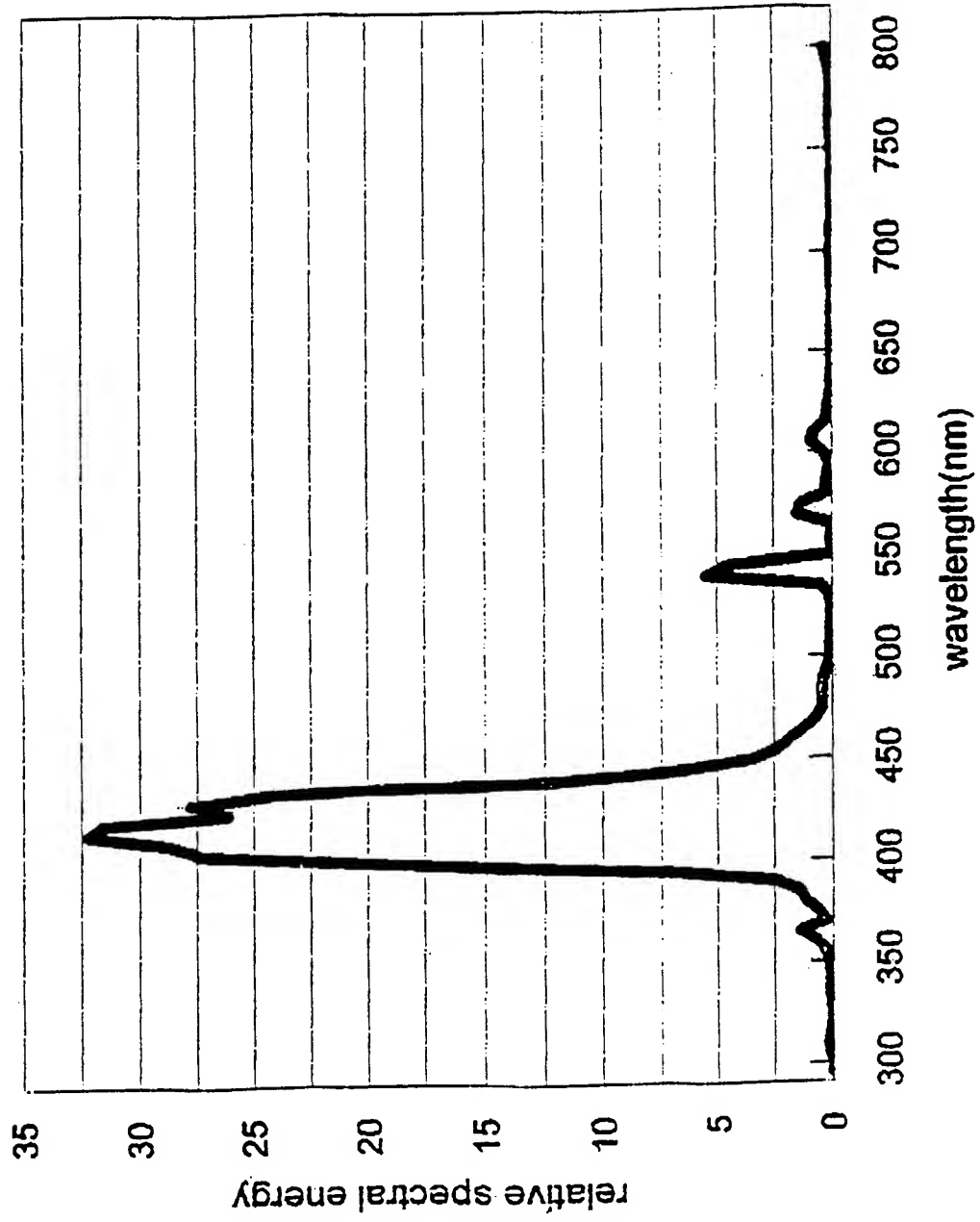
13.

Apparatus according to claim 10 incorporating one lamp having two red emitting legs and one lamp having a blue and a red emitting leg.

14.

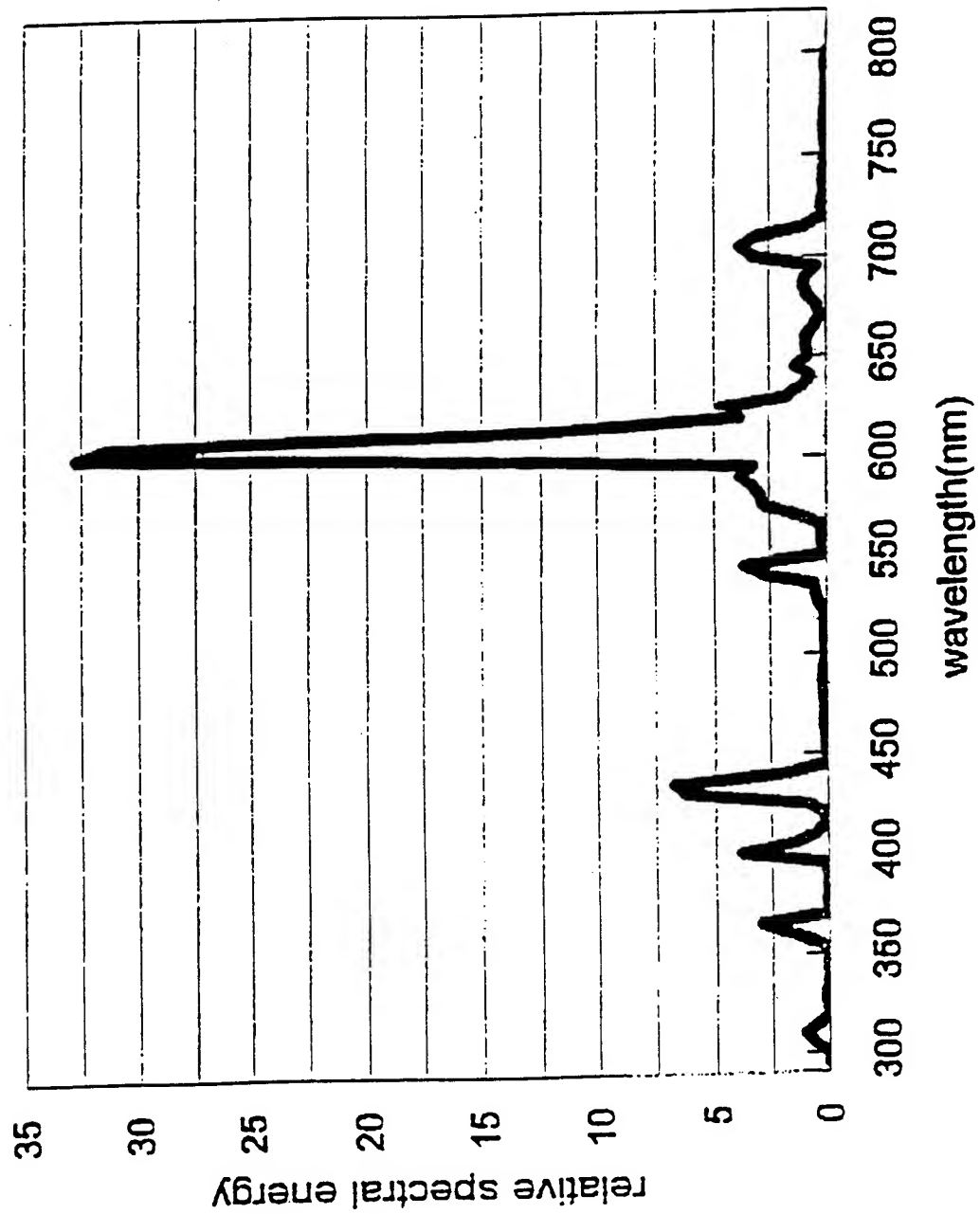
Apparatus according to claim 6 and 7, wherein the reflector is applied as internal reflective coating onto the inner bulb wall of each lamp (5, 6, 7, 8, 9, 10).

Fig. 1



Spectral energy distribution of a blue lamp

Fig. 2



Spectral energy distribution of a red lamp

Fig. 3

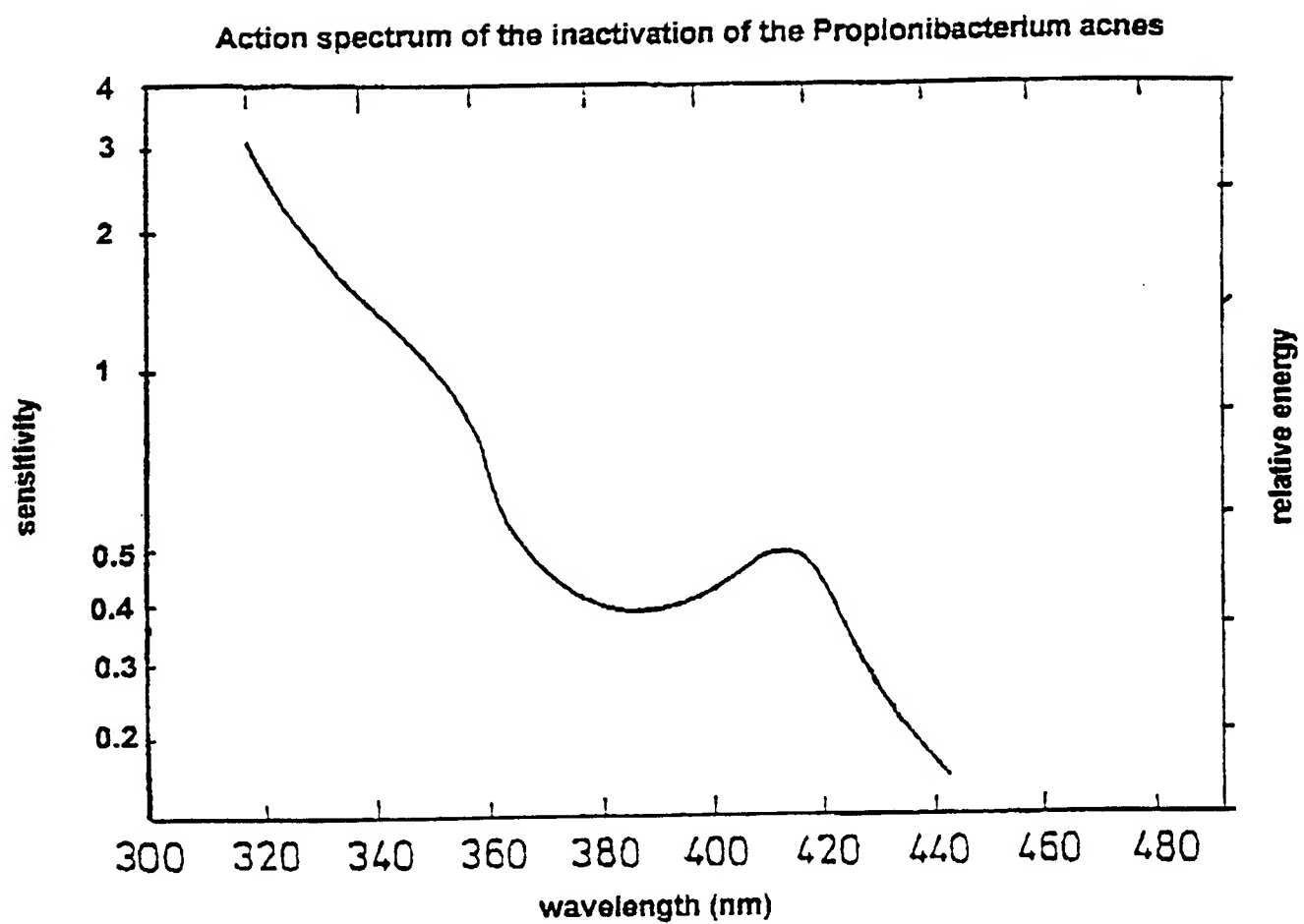
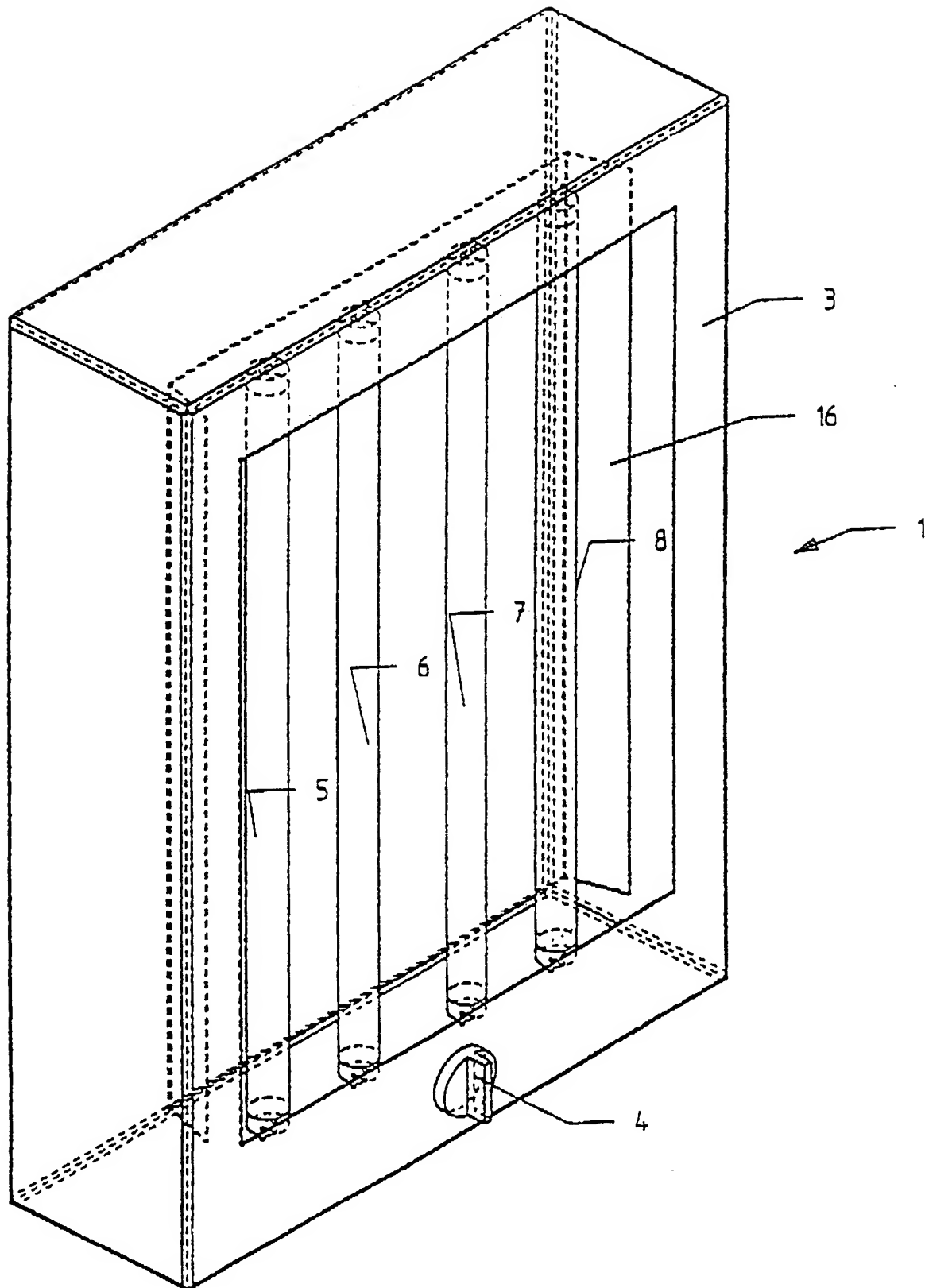


Fig. 4





# INTERNATIONAL SEARCH REPORT

In ational Application No

PCT/EP 98/07884

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 A61N5/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 14899 A (OPTOMED OPTO MED SYS GMBH ;WILKENS JAN (DE)) 23 May 1996 (1996-05-23) page 8, line 8 page 9, line 19 - page 10, line 4 page 12, line 1 - line 25 page 17, line 14 - line 31 claims 1-4,12	5,7,14
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

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Date of the actual completion of the international search

20 July 1999

Date of mailing of the international search report

27/07/1999

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 41 43 168 A (REHA TEC VERTRIEBSGES FUER MED) 1 July 1993 (1993-07-01) column 1, line 26 - line 29 column 1, line 63 - column 2, line 4 column 2, line 25 - line 35 ---	5
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# INTERNATIONAL SEARCH REPORT

international application No.

PCT/EP 98/ 07884

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-4  
because they relate to subject matter not required to be searched by this Authority, namely:  
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy.
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims: it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT


Information on patent family members

In ternational Application No

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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b> <b>A61K 41/00</b>	<b>A2</b>	<b>(11) International Publication Number:</b> <b>WO 00/40266</b> <b>(43) International Publication Date:</b> 13 July 2000 (13.07.00)
<b>(21) International Application Number:</b> PCT/US99/29974 <b>(22) International Filing Date:</b> 16 December 1999 (16.12.99)  <b>(30) Priority Data:</b> 09/225,026                      4 January 1999 (04.01.99)                      US  <b>(71) Applicant:</b> THE GENERAL HOSPITAL CORPORATION d/b/a [US/US]; Massachusetts General Hospital, 55 Fruit Street, Boston, MA 02114 (US).  <b>(72) Inventor:</b> ANDERSON, Richard, Rox; 339 Marrett Road, Lexington, MA 02421 (US).  <b>(74) Agents:</b> ROTHENBERGER, Scott, D. et al.; Nutter, McClen- nen & Fish, LLP, One International Place, Boston, MA 02110-2699 (US).		<b>(81) Designated States:</b> CA, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>Without international search report and to be republished upon receipt of that report.</i>
<b>(54) Title:</b> TARGETING OF SEBACEOUS FOLLICLES AS A TREATMENT OF SEBACEOUS GLAND DISORDERS  <b>(57) Abstract</b> <p>Laser treatments of sebaceous gland disorders with laser sensi- tive dyes are disclosed. A preferred laser treatment includes topical application of an energy activatable material to the skin followed by laser irradiation.</p> <p><b>Blue staining of the sebaceous gland and hair follicle by methylene blue in an aqueous based lotion</b></p> 		

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## TARGETING OF SEBACEOUS FOLLICLES AS A TREATMENT OF SEBACEOUS GLAND DISORDERS

### BACKGROUND OF THE INVENTION

5 Skin disorders, such as acne, can be irritating and embarrassing. The major disease of skin associated with sebaceous follicles, is acne vulgaris. This is also the most common reason for visiting a dermatologist in the United States. There are many treatments, but no cures for acne. These include antibiotics (which inhibit growth of *p. acnes* bacteria which play a role in acne), retinoids such as Accutane<sup>®</sup> (isotetinoin, which  
10 reduces sebaceous gland output of sebum), and antimicrobials such as benzoyl peroxide. Acne lesions result from the rupture of a sebaceous follicle, followed by inflammation and pus (a "whitehead"), or by accumulation of plugged material in the sebaceous follicle (a "blackhead"). This pathophysiology has two major requirements: (1) plugging of the upper portion of the follicle, and (2) an increase in sebum production. The upper portion  
15 of the follicle, i.e., the "pore" into which sebum is secreted and which is directly in communication with the skin surface, is called the infundibulum. A plug forms in the infundibulum from cells, sebum, bacteria, and other debris. The sebaceous gland continues to produce sebum (an oily fluid), stretching the infundibulum until either it or some lower portion of the follicles ruptures.

20 Generally, only a minority of sebaceous hair follicles on the face and upper back develop acne lesions. Therefore, it is likely that some structural differentiation predisposes a fraction of the follicles to develop acne. In most males, acne is worst in the teenage years and then subsides, suggesting that a subpopulation of follicles may be present which ultimately self-destruct. In women, teenage acne is often followed by  
25 menstrual acne flares well into adulthood. Since both plugging of the infundibulum and high sebaceous gland activity are necessary for an acne lesion to develop, it is likely that the predisposing factors for the follicles which become infected are (1) an infundibulum shape which is easily plugged, and/or (2) a hyperactive sebaceous gland.

30 Unlike medical dermatology, most laser dermatology treatments are actually "cures" -- producing a permanent anatomic, microsurgical effect on the skin. This includes skin resurfacing, portwine stain treatment, tattoo and pigmented lesion removal, and hair removal. Selective photothermolysis or controlled skin ablation with lasers or other extremely intense light sources, might therefore be capable of curing skin disorders, such as acne, if appropriately targeted to the primary site(s) of pathophysiology.

## SUMMARY OF THE INVENTION

The present invention is based, at least in part, on the discovery that energy activatable materials, such as chromophores, described *infra*, in combination with an energy source, e.g., photo (light) therapy, can be used to treat sebaceous gland disorders, e.g., eliminate, inhibit, or prevent occurrence or reoccurrence of the skin disorder. A preferred example of such a sebaceous gland disorder is acne.

The present invention pertains to methods for treating skin disorders associated with sebaceous follicles by topically applying an energy activatable material to a section of skin afflicted with a sebaceous gland disorder, wherein the material is activated by energy which penetrates outer layers of epidermis. A sufficient amount of the material infiltrates the afflicted section of skin and is exposed to sufficient energy to cause the material to become photochemically or photothermally activated, thereby treating the sebaceous gland disorder. In one embodiment, the sebaceous gland disorder is acne. Suitable energy sources include flash lamp based sources and lasers, such as Nd: YAG, Alexandrite, flash lamp-pumped dyes and diodes. Alternatively, the energy source can also be a continuous wave energy source. In preferred embodiments, the energy activatable material is a laser sensitive chromophore, e.g., a chromophore which is capable of being photostimulated by a laser, e.g., a dye. In a particularly preferred embodiment, the chromophore is methylene blue.

The present invention also pertains to methods for modifying the opening to the infundibulum by topically applying an energy activatable material to the opening to the infundibulum, wherein the material is activated by energy which penetrates outer layers of epidermis. Preferably, the perfusion of the material into the pore opening and/or sebaceous gland is increased by iontophoresis. A sufficient amount of the material infiltrates spaces about the infundibulum and the infundibulum is exposed to sufficient energy to cause the material to become photochemically or photothermally activated, thereby modifying the opening to the infundibulum. In one embodiment, the opening to the infundibulum is enlarged. In another embodiment, the opening to the infundibulum is decreased. In still another embodiment, the opening to the infundibulum is altered such that pore pluggage will not occur, e.g., the infundibulum is reshaped such that excess

sebum, oils, dirt and bacteria will not cause pore pluggage to occur, resulting in a black head (comedon) or white head (miliun).

The present invention also pertains to methods for down regulating, e.g., decreasing, the oil/lipid output production of the sebaceous gland. Application of the energy activatable material to the pilosebaceous unit, e.g., the sebaceous gland, followed by stimulation by an energy source can cause selective permanent physical alteration to the sebaceous gland and/or follicle such that surrounding tissue remains unaffected. The physical alteration to the sebaceous gland and/or follicle results in diminished production of sebum.

The present invention further pertains to methods for modifying the pilosebaceous unit by topically applying an energy activatable material to the pilosebaceous unit, wherein the material is activated by energy which penetrates into the dermis and into the outer layers of epidermis. A sufficient amount of the material infiltrates the pilosebaceous unit and the pilosebaceous unit is exposed to sufficient energy to cause the material to become photochemically or photothermally activated, thereby modifying the pilosebaceous unit. In one embodiment, the pilosebaceous unit is treated such that sebum production is diminished. A decrease in pore pluggage can occur, as a result of the diminishment of sebum production. In one preferred embodiment, treatment of the pilosebaceous unit by the present invention results in elimination of pore pluggage, e.g., the pilosebaceous unit is treated such that excess sebum, oils, dirt and bacteria will not cause pore pluggage to occur, resulting in a black or white head.

## BRIEF DESCRIPTION OF THE DRAWINGS

The file of this patent contains at least one drawing executed in color. Copies of this patent with color drawings will be provided by the Patent and Trademark Office upon request and payment of the necessary fee.

Figure 1 is a cross-sectional view of hair shafts with pore pluggage and energy activatable material.

Figure 2 is a cross-sectional view of a plugged follicle after an energy activatable material has been allowed to penetrate the follicle and sebaceous gland.

Figure 3 is a cross-sectional view of hair shafts which include an energy activatable material during irradiation with an energy source, e.g., a laser.

Figures 4a and 4b are cross-sectional views of hair shafts where the pore opening and infundibulum are modified by the process of the invention.

Figures 5a and 5b are cross-sectional views of hair shafts where sebaceous glands are modified by the process of the invention.

5        Figures 6a and 6b are cross-sectional views of hair shafts where debris within the pore is removed by the process of the invention.

Figures 7a and 7b are cross-sectional views of hair shafts where the pore opening, infundibulum and sebaceous glands are modified by the process of the invention and where debris within the pore is also removed.

10        Figure 8 depicts methylene blue which has been iontophoretically administered into the sebaceous glands and/or infundibulum of an individual.

Figure 9 depicts light microscopy of blue staining of the epidermis, sebaceous glands and hair follicles.

15        Figure 10 is a color photograph depicts light microscopy of blue staining of the epidermis, sebaceous glands and hair follicles.

## DETAILED DESCRIPTION OF THE INVENTION

The features and other details of the invention will now be more particularly described and pointed out in the claims. It will be understood that the particular  
20        embodiments of the invention are shown by way of illustration and not as limitations of the invention. The principle features of this invention can be employed in various embodiments without departing from the scope of the invention.

The present invention is based, at least in part, on the discovery that energy activatable materials, such as chromophores, described *infra*, in combination with an  
25        energy source, e.g., photo (light) therapy, can be used to treat sebaceous gland disorders, e.g., eliminate, remove, or prevent occurrence or reoccurrence of the sebaceous gland disorder. Examples of such sebaceous gland disorders include sebaceous gland hyperplasia, acne vulgaris and acne rosacea. A preferred example of such a sebaceous gland disorder is acne.

30        In one aspect, the present invention is drawn to methods for treating sebaceous gland disorders by topically applying an energy activatable material to a section of skin afflicted with a sebaceous gland disorder. The energy activatable material is energetically



stimulated by an energy source. For example, the energy activatable material can be a chromophore which absorbs at least one frequency band of energy which penetrates outer layers of epidermis. A sufficient amount of the material infiltrates the skin and the section of skin is exposed to at least one frequency band of energy so as to impart, to the material, sufficient energy to cause the material to become photochemically or photothermally activated which brings about a physiological change, thereby treating the sebaceous gland disorder. In one embodiment, the sebaceous gland disorder is acne. Suitable energy sources include a wide range of electromagnetic sources including, energy emitted by the sun, Rf (radio frequency) energy, energy from microwave generators, ultraviolet light generators, flash lamp based sources and lasers, such as Nd: YAG, Alexandrite, and flash lamp-pumped dyes and diodes. Alternatively, the energy source can be a continuous wave energy source. In preferred embodiments, the energy activatable material is a laser sensitive chromophore, e.g., a chromophore which is capable of being photostimulated by a laser. In a particularly preferred embodiment, the chromophore is methylene blue.

The present invention also pertains to methods for modifying the opening to the infundibulum by topically applying an energy activatable material to the opening to the infundibulum, wherein the material absorbs at least one frequency band of energy which penetrates outer layers of epidermis. A sufficient amount of the material infiltrates spaces about the infundibulum and the section of skin is exposed to at least one frequency band of energy so as to impart to the material, sufficient energy to cause the material to become photochemically or photothermally activated, thereby modifying the opening to the infundibulum. In one embodiment, the opening to the infundibulum is altered such that pore pluggage will not occur, e.g., the infundibulum is reshaped such that excess sebum, oils, dirt and bacteria will not cause pore pluggage to occur, resulting in a blackhead (comedon) or white head (miliun). In a preferred embodiment, the opening to the infundibulum is opened.

The present invention further pertains to methods for modifying the pilosebaceous unit by topically applying an energy activatable material to the pilosebaceous unit, wherein the material absorbs at least one frequency band of energy which penetrates outer layers of epidermis. A sufficient amount of the material infiltrates the pilosebaceous unit and the section of skin is exposed with at least one frequency band of energy so as to

impart to the material, sufficient energy to cause the material to become photochemically or photothermally activated, thereby modifying the pilosebaceous unit. In one embodiment, the pilosebaceous unit is treated such that sebum production is diminished, thereby resulting in decreased pore pluggage. In one preferred embodiment, treatment of the pilosebaceous unit by the present invention results in elimination of pore pluggage, e.g., the pilosebaceous unit is treated such that excess sebum, oils, dirt and bacteria will not cause pore pluggage to occur, resulting in a black or white head.

Sebaceous glands are components of the pilosebaceous unit. They are located throughout the body, especially on the face and upper trunk, and produce sebum, a lipid-rich secretion that coats the hair and the epidermal surface. Sebaceous glands are involved in the pathogenesis of several diseases, the most frequent one being acne vulgaris. Acne is a multifactorial disease characterized by the occlusion of follicles by plugs made out of abnormally shed keratinocytes of the infundibulum (upper portion of the hair follicle) in the setting of excess sebum production by hyperactive sebaceous glands. Various treatment modalities for acne exist that aim in modifying the rate of sebum secretion by the sebaceous glands (e.g., retinoids), inhibiting the bacterial overgrowth in the follicular duct (antibiotics), or decreasing the inflammation of acne lesions (anti-inflammatory agents). Most of these agents are not curative of acne and simply control the disease by affecting one of the aforementioned pathogenic factors. Oral retinoids are a notable exception: they are potent drugs that can achieve a significant cure rate for acne, but their side effect profile often limits their use. Advantages of the present invention include that treatment can permanently alter the pilosebaceous unit, rendering it no longer susceptible to pore pluggage without the side effects associated with oral retinoids.

The term "sebaceous gland disorders" is intended to include those sebaceous gland disorders which can be treated by an energy activatable material. The energy activatable material can be a photothermally or photochemically activatable, e.g., reactive, material which is susceptible to photoactivation or stimulation, e.g., light, i.e., laser stimulation. The activation or excitation of the material generates reactive species, such as radicals, which can interact with the site of pore pluggage, inflammation, bacteria, viruses, etc. and promote, for example, oxidation of those agents which are associated with the disorder. Examples of sebaceous gland disorders which can be treated by the

methods of the invention include sebaceous gland hyperplasia, acne vulgaris and acne rosacea. Of particular importance is treatment of acne by the method of the invention.

The term "pluggage" is intended to obstruction of the pores by the buildup of sebum, dirt, bacteria, mites, oils, and/or cosmetics in the pore, e.g., about the infundibulum.

The term "acne" is art recognized and is intended to include acne vulgaris and acne rosacea. Acne vulgaris the most common skin disease seen in dermatologic practice which affects approximately 17 million people in the United States. Its precise cause is unknown, although abnormal keratin production with obstruction of the follicular opening, increased production of sebum (lipids secreted by the androgen-sensitive sebaceous glands), proliferation of *Propionibacterium acnes* (anaerobic follicular diphtheroids), follicular rupture and follicular mites (demodex) are commonly associated with acne.

Skin conditions such as acne are believed to be caused or exacerbated by excessive sebum flow produced by sebaceous glands most of which are adjacent to and discharge sebum into, hair follicles. Sebum is composed of keratin, fat, wax and cellular debris. Sebum forms a moist, oily, acidic film that is mildly antibacterial and antifungal and may to some extent protect the skin against drying. It is known that the bacteria which contribute to acne, *Propionibacterium acnes* or (P-acnes), grows in sebum. Significant sebum flow in humans begins at puberty. This is when acne problems generally arise.

The phrase "energy activatable material" is intended to include those agents which, when stimulated by energy from an energy source, e.g., a laser source, become energetically stimulated, e.g., photothermally or photochemically. These materials can be stimulated by various energy sources, e.g., electromagnetic sources, such as a continuous wave source, a laser source, flashlamp, ultraviolet light, microwaves, infrared light, etc. The material absorbs the energy which causes the material to become thermally or chemically active.

Suitable materials useful in the invention include metal oxides, such as aluminum oxide, iron oxides, carbon particles (graphite and amorphous carbon particles) and natural and synthetic chromophores. The term "chromophore" is art recognized and is intended to include those compounds which absorb energy at a given wavelength, often by sites of

unsaturation, carbon-oxygen bonds, and/or charged species, or combinations thereof.

Suitable chromophoric groups include nitro groups, azo, quinoids, alkylene units, carbonyls, esters, alkynes, aldehydes, carboxylic acids, and those groups associated with  $n \rightarrow \pi^*$  and  $\pi \rightarrow \pi^*$  transitions. Preferred energy activatable materials include laser sensitive

5 dyes, for example, methylene blue, indocyanine green and those in U.S. Patent No. 4,651,739, issued March 24, 1987, the entire contents of which are incorporated herein by reference. Preferred dyes are those dyes which are activated by laser stimulation.

Preferred laser sensitive dyes are those which are FDA approved. A preferred dye, a laser sensitive dye, is methylene blue. In one embodiment, the laser sensitive dye is not  
10 indocyanine green. In another embodiment, the energy activatable material is not carbon particles.

The energy activatable materials of the present invention undergo energetic activation, by photothermal or photochemical stimulation. The term "photothermal" interaction (excitation or stimulation) is art recognized and is intended to include  
15 interactions which are due to conversion of energy into heat. Photothermal activation of an energy activatable material causes the material to be heated, thereby heating the local area, preferably selectively with a significant temperature increase of such that unwanted material, e.g., tissues, oils, bacteria, viruses, dirt, etc. such that the surrounding tissue remains unaffected. The photothermally activated material can form biologically reactive  
20 products. Photothermal processes can involve oxidation of, for example, cell walls, extracellular matrix components, nuclei, etc. As a result of photothermal stimulation, the infundibulum can be reshaped as a result of collagen shrinkage. Additionally, the process can cause cell death in the sebaceous gland, thereby decreasing production of sebum.

The term "photochemical" is art recognized and is intended to include molecular  
25 bond breaking where one or more absorbed photon excites the molecule to a higher electronic, vibrational, or rotational state. Photochemical stimulation of an energy activatable material causes the material to enter an excited energy state wherein energy is absorbed, e.g., by the chromophore, whereby bonds within the energy activatable material are broken and forms reactive by products such as radical species. These reactive by  
30 products can interact with the localized surrounding tissue area such that the tissue is cleansed of unwanted material, e.g., oils, bacteria, viruses, dirt, etc. As a result of photochemical stimulation, the infundibulum can be reshaped as a result of collagen

shrinkage. Additionally, the photochemical process can cause cell death in the sebaceous gland, thereby decreasing production of sebum.

The photochemically activated material can return to the ground state or it can decompose into biologically reactive fragments. Photochemical processes can involve oxidation or radical polymerization of, for example, cell walls, extracellular matrix components, nuclei, etc.

Photochemical activation of energy activatable materials can be achieved over long time periods with energy of low intensity. For example, treatment of sebaceous gland disorders could be treated with an energy activatable material contained in a cream or lotion applied to the skin prior to long periods of exposure to the sunlight, e.g., while participating in sports or sitting on the beach.

The energy activatable materials of the present invention do not undergo fragmentation or vaporization such that the energy activatable material causes photo-mechanical destruction of the surrounding tissue, e.g., the energy activatable materials do not undergo violent decomposition, i.e., the energy activatable materials do not explode. Preferably, therefore, the energy activatable material is subjected to a sufficient energy which causes the energy activatable material to be photochemically or photothermally stimulated without violent decomposition and harm to surrounding tissue (See for example Ton G. van Leeuwen et al. Optical-Thermal Response of Laser-Irradiated Tissue, "Pulsed Laser Ablation of Soft Tissue" ed. A. J. Welch and M.J. C. van Gemert, Chapter 21, pg 709, Plenum Press, New York, 1995).

Not to be limited by theory, stimulation of the energy activatable material, e.g., a chromophoric agent, can cause oxidation and decomposition of the unwanted material(s), thereby degrading and removing unwanted material from the pore. Additionally, this treatment can also cause the opening to the infundibulum to become modified, e.g., the pore opening is enlarged or the pore opening is constricted or closed. Consequently, alteration of the pore opening, such as enlargement of the pore opening, a change in the pore shape, or constriction of the pore opening prevents unwanted dirt, bacteria, viruses and/or oils from building up in the treated area, e.g., the infundibulum.

Photothermal alteration of the sebaceous gland, the follicle infundibulum, or both requires the deposition of sufficient energy to cause local heating to temperatures capable of cell killing (e.g., killing of sebocytes, stem cells, or bacterial cells), protein

denaturation (e.g., denaturation of basement membranes and/or perifollicular collagen), or vaporization of tissue. In general, these temperatures range from about 60 - 100°C for the first two effects, and somewhat over 100°C (e.g., about 120°C) for vaporization of tissue.

The amount of a light-absorbing dye which must be present for a given local  
5 fluence of a pulse of optical energy to cause these photothermal effects, can be determined by considering the basic principles of selective photothermolysis. If the pulse of optical radiation is delivered within the thermal relaxation time for the target structure, heat flow from the target is limited during the pulse. The preferred pulse duration is therefore about equal to or less than the thermal relaxation time of the given target, which  
10 measured in seconds is approximately equal to the square of the target's shortest dimension measured in millimeters. For example, the infundibulum portion of most sebaceous follicles on the face is approximately 0.3 mm in diameter, which corresponds approximately to a thermal relaxation time of about 0.1 seconds (100 ms).

The sebaceous gland is similar in diameter, but may on the nose be as large as  
15 1 mm. Although thermal confinement is achieved with pulses shorter than the target's thermal relaxation time, very short pulses cause unwanted mechanical injury which can rupture the follicles. For example, the method of Tankovich, U.S. Patents 5,752,949, 5,425,728, 5,226,907 and 5,752,948, employs explosive, photomechanical mechanism to damage hair follicles. Skin eruption has been observed on patients with an acne-like skin  
20 caused by the Tankovich treatment.

The fatty acids, sebum, and bacteria present in sebaceous follicles is extremely irritating if not contained by the follicle. In acne vulgaris, rupture of the follicle is the event which stimulates inflammation to form a "pimple", including accumulation of pus to form a "whitehead". It is therefore desired to avoid rupture of the follicle or sebaceous  
25 gland. Such mechanical injury can be avoided by using pulses longer than about 0.1 milliseconds. Thus, the preferred range of pulse duration is 0.1 - 100 ms, and the ideal pulse duration is about 10 - 50 ms.

When thermal confinement during the pulse is achieved, the local temperature rise is given approximately by  $\Delta T = E\mu(\rho c)^{-1}$ , where E is the local fluence at the target,  $\mu$  is  
30 the local absorption coefficient of the target, and  $\rho c$  is heat capacity of the target. It is highly preferred to use wavelengths of the optical spectrum in which natural skin pigments exhibit weaker absorption (to minimize heating at other sites), and which

penetrate well to the anatomic depth of the infundibulum and/or sebaceous glands. The orange, red, and near-infrared wavelength region (600 - 1200 nm) is therefore most appropriate. At these wavelengths, there is very little absorption by natural skin pigments other than melanin.

5 Melanin is often present in coarse hairs, but in general is absent or nearly absent in the vellus hairs present in the sebaceous follicles associated with acne vulgaris. The exception to this is when a "blackhead" (an open comedo) is present, which consists of a plugged sebaceous follicle containing melanin or melanin-like oxidized substances which absorb light. To a reasonable approximation, therefore, there is no optical absorption in  
10 the 600 - 1200 nm wavelength region in most sebaceous follicles. The tolerable fluence for human skin of an optical pulse in this part of the spectrum is about 5 - 100 J/cm<sup>2</sup>, depending on the amount of epidermal melanin and on wavelength. Skin surface-cooling methods can also be used to increase this tolerable fluence. Ideally, an amount of dye can be taken up by the sebaceous follicle such that a pulse delivering less than  
15 100 J/cm<sup>2</sup> can produce desired photothermal effects. The target absorption coefficient,  $\mu$ , is approximately equal to 2.3, times the local molar concentration [d] of the dye in the follicle, times the molar extinction coefficient  $\epsilon$  for that dye. The value of  $\rho c$  for most tissues is about 4 Jcm<sup>-3</sup>C<sup>-1</sup>. Many dyes have molar extinction coefficients of 10<sup>3</sup>-10<sup>5</sup> M<sup>-1</sup>cm<sup>-1</sup>.

20 From this information, the local dye concentration needed in the follicle can be estimated, and used to direct therapy. For example, to reach a temperature of approximately 80°C, a temperature rise  $\Delta T$  would be about 50°C because the ambient skin temperature is typically about 30°C. At a fluence of  $E = 10$  J/cm<sup>2</sup> (easily tolerated by most skin types), the local value of  $\mu$  must therefore be about  $\mu = \Delta T \rho c / E =$   
25 (50)(4)(10), or 20 cm<sup>-1</sup>. The concentration of a dye to achieve this absorption coefficient at the target, can be determined. Preferred dyes such as methylene blue have molar extinction coefficients about  $\epsilon = 10^4$  M<sup>-1</sup>cm<sup>-1</sup>, which require uptake to a dye concentration [d] in the follicle of about  $[d] = \mu / (2.3\epsilon) = 20 / (2.3 \times 10^4)$ , or about 10<sup>-3</sup>M.

Thus, about 1 mM concentration of these dyes is sufficient to achieve the desired  
30 photothermal effects to inhibit acne vulgaris. Because a factor of 10 was allowed in the tolerable fluence in the above example, it would be possible (minimally) to practice the invention with values of  $\mu$  as low as about 2 cm<sup>-1</sup>, corresponding to dye concentration of

about 0.1 mM (100  $\mu$ M). However, it is preferred in practice to provide a safety margin between the fluence necessary for the desired photothermal effect on sebaceous glands and/or infundibulum, and the maximum fluence tolerated by human skin. The preferred dye concentration in the follicle infundibulum and/or sebaceous gland is therefore greater than 0.1 mM for most of the preferred dyes, and more generally a sufficient concentration to achieve a local absorption coefficient of greater than about  $10\text{ cm}^{-1}$ .

Preferably, the energy source produces an exposure area of between about 3 to about 100 millimeters to treat a section of skin afflicted with a sebaceous gland disorder, as described above. The fluence is limited such that the skin is not damaged while the sebaceous gland disorder is treated, e.g., eradicated, inhibited, or prevented. The fluence is controlled such that localized destruction to the undesired sebaceous gland disorder occurs with little or no non-specific necrosis of surrounding tissue. For example, at 755 nm, up to  $100\text{ J/cm}^2$  can be administered to a very fair Caucasian individual without damage to the skin. The amount of energy a darker skin could tolerate without damage to the skin would be less. A person having skill in this art can ascertain the amount of energy and type of energy to be expended to achieve the results desired.

Suitable energy sources include light-emitting diodes, incandescent lamps, xenon arc lamps, lasers or sunlight. Suitable examples of continuous wave apparatus include, for example, diodes. Suitable flash lamps include, for example pulse dye lasers and Alexandrite lasers. Representative lasers having wavelengths strongly absorbed by chromophores, e.g., laser sensitive dyes, within the epidermis and infundibulum but not sebaceous gland, include the short-pulsed red dye laser (504 and 510 nm), the copper vapor laser (511 nm) and the Q-switched neodymium (Nd):YAG laser having a wavelength of 1064 nm that can also be frequency doubled using a potassium diphosphate crystal to produce visible green light having a wavelength of 532 nm. Further examples of lasers which are suitable for use as energy sources include those in the following table of lasers:



## Types of Laser

### Commercial Laser Types, Organized by Wavelength

	Wavelength, $\mu\text{m}$	Type	Output type and power
5	0.523	Doubled Nd-YLF	Pulsed, watts
	0.532	Doubled Nd-YAG	Pulsed to 50 W or CW to watts
	0.534, 0.538	He-Cd	CW, milliwatts, in white-light laser
	0.5435	He-Ne	CW, 1-mW range
	0.578	Copper vapor	Pulsed, tens of watts
10	400-700 nm	Pulsed Dye	tens of Joules
	514.5 nm	Ar Ion	tens of watts
	530.9 nm	Kr Ion	approximately 5 watts
	750-900 nm	GaAlAs semiconductor diode array	tens of watts depending on number of elements
	1060 nm	Nd:YAG	tens of watts

15 Another desirable property of thermal and photochemical energy activatable material is an absorption spectrum in the range of 600-1300 nm; this minimizes surrounding blood from absorbing light intended for the material (hemoglobin absorbs most strongly at the violet end of the spectrum).

20 The depth of penetration of the energy, e.g., light, emitted from the energy source, such as a laser, is dependent upon its wavelength. Wavelengths in the visible to near IR have the best penetration and are therefore best for use to treat the sebaceous gland and infundibulum located within the dermis.

25 Photochemical cell killing preferably uses chromophores with peak absorbance in the 600-1300 nm range. Whether photostability is important depends on the mechanism of photochemical cell killing. For example, chromophores which kill by the interaction with oxygen to produce singlet state oxygen, high photostability is desirable, so that such production continues for as long as possible before the chromophore breaks down.

30 For chromophores which kill by virtue of the degradation of the chromophore to a toxic reaction product, photostability is generally not desired, since the breakdown of the chromophore is the process which achieves the desired effect.

35 In the present process, selective photoactivation is employed whereby an energy (light) source, e.g., a laser, is matched with a wave-length to the absorption spectrum of the selected energy activatable material, preferably a chromophoric agent, e.g., methylene blue at 661 nm. For example, an energy activatable material, adapted to accumulate selectively in the infundibulum and/or the sebaceous gland, is first applied to the region

of afflicted skin to be treated. Following absorption of the energy activatable material, the accumulated material, is exposed to an energy source, e.g., a laser, capable of producing a wavelength readily absorbed by the energy activatable material thereby selectively photothermally heating or photochemically treating those regions of the dermis known to have trapped oils, bacteria, viruses, dirt, etc. i.e., the pilosebaceous unit which includes the pore opening, infundibulum and sebaceous gland. Because the energy activatable material is selectively concentrated within or about these undesired deposits, the deposits are degraded by the heat and/or radical species generated from the energy activated material. There is minimal to no destruction of normal adjacent epidermal and dermal structures.

Preferably, the treatment of the invention modifies the pore opening to the infundibulum such that the geometry, e.g., the shape, of the opening is permanently altered. Adjustment of the concentration of the energy activatable material and the amount of energy applied by the energy source effects constriction, closure, or opening of the pore, thereby preventing accumulation of dirt, oils, bacteria, or viruses in that follicle. The operator will need to assess the parameters to illicit the desired effect and will be determined on a patient by patient basis. Generally, it is most desirable to alter the shape of the pore, leaving the pore enlarged and no longer prone to buildup of sebum and/or foreign materials which would cause pore pluggage.

As previously stated, the present invention involves the use of energy sources, e.g., lasers, to target sebaceous glands and cause their photothermal or photochemical destruction. Sebaceous glands are mainly composed of amorphous lipid material and do not contain any obvious endogenous chromophores. In order to achieve selective photocoagulation of sebaceous glands and confine the extent of thermal injury in the surrounding tissue, a topically applied energy activatable material with selective distribution to the pilosebaceous unit can be utilized. The introduction of a energy activatable material in sebaceous glands followed by exposure to energy (light) with a wavelength that corresponds to the absorption peak of the chromophore, will increase the local absorption of light in tissue and lead to selective thermal damage of sebaceous glands.

The infundibulum is a critical site in the pathogenesis of many of the disease states, especially acne. There is evidence that abnormal proliferation and desquamation

of infundibular keratinocytes leads to the formation of microcomedones and, later on, to clinically visible follicular "plugs" or comedones. Clinically, it appears that some sebaceous follicles are more prone than others to develop acne lesions, possibly due to an inherent structural difference or functional abnormality of the infundibulum, that predisposes them to form plugs and occlude. The self-resolving nature of acne in most patients may reflect the elimination of such "acne-prone" follicles which are eventually replaced by normal skin or fibrosis after repeated bouts of inflammation. If the architecture of the infundibulum is important in the pathogenesis of acne, then selective destruction of this portion of the follicle through energy activatable material-assisted energy, e.g., laser, targeting can help eliminate or correct the "pathologic" site by creating a distended follicular opening that is able to extrude any occluded material.

The process of selective energy activation according to the present invention uses energy sources, e.g., light, e.g., lasers, matched to a particular energy activatable material. In the case of photothermal activation, to facilitate temperature rise, the pulse duration time period should be shorter than that of the thermal relaxation time for the energy activatable material. The thermal relaxation time is defined as the time it takes for a structure to cool to 50% of its peak temperature immediately following exposure to a light source capable of providing enough energy to photoactivate the chromophore. Therefore, selective treatment of those dermal regions containing an energy activatable material, e.g., a laser sensitive dye, will occur when exposed to millisecond light pulses. A laser delivering pulses in the range of 1 to 50 milliseconds (ms) has been found to adequately photoactivate energy activatable materials, such as carbon particles, iron oxide particles and laser sensitive dyes, e.g., chromophoric materials, deposited within the hair follicle matrix, e.g., about the infundibulum and sebaceous gland. Different types of energy activatable materials require variations in the energy dose applied and the type of energy source necessary to effect treatment of the afflicted skin area. When applied to the skin of the region to be treated, the energy activatable material is absorbed within the hair follicle matrix and upon exposure, the energy will be concentrated in those critical areas of the follicle matrix where the energy activatable material has collected e.g., the pilosebaceous unit including the sebaceous gland, infundibulum and pore opening.

Delivery of the energy activatable material, preferably methylene blue or other FDA approved dyes, to the follicle matrix can be achieved by topical application,

injection, liposome encapsulation technology, massage, iontophoresis or ultrasonic technology, or other means for delivery of compounds into the dermal region of the skin, e.g., pharmaceutically acceptable carriers.

The phrase "pharmaceutically acceptable carrier" as used herein means a pharmaceutically acceptable material, composition or vehicle, such as a liquid or solid filler, diluent, excipient, solvent or encapsulating material, involved in carrying or transporting a energy activatable material of the present invention within or to the subject such that it can performs its intended function. Each carrier must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not injurious to the patient. Some examples of materials which can serve as pharmaceutically acceptable carriers include: sugars, such as lactose, glucose and sucrose; starches, such as corn starch and potato starch; cellulose, and its derivatives, such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; powdered tragacanth; malt; gelatin; talc; excipients, such as cocoa butter and suppository waxes; oils, such as peanut oil, cottonseed oil, safflower oil, sesame oil, olive oil, corn oil and soybean oil; glycols, such as propylene glycol; polyols, such as glycerin, sorbitol, mannitol and polyethylene glycol; esters, such as ethyl oleate and ethyl laurate; agar; buffering agents, such as magnesium hydroxide and aluminum hydroxide; alginic acid; pyrogen-free water; isotonic saline; Ringer's solution; ethyl alcohol; phosphate buffer solutions; and other non-toxic compatible substances employed in pharmaceutical formulations. Preferred carriers include those which are capable of entering a pore by surface action and solvent transport such that the energy activatable material is carried into or about the pore, e.g., into the sebaceous gland, to the plug, into the infundibulum and/or into the sebaceous gland and infundibulum.

Wetting agents, emulsifiers and lubricants, such as sodium lauryl sulfate and magnesium stearate, as well as coloring agents, release agents, coating agents, sweetening and perfuming agents, preservatives and antioxidants can also be present in the compositions. Liquid dosage forms for topical administration of the compounds of the invention include pharmaceutically acceptable emulsions, microemulsions, solutions, creams, lotions, ointments, suspensions and syrups. In addition to the active ingredient, the liquid dosage forms may contain inert diluents commonly used in the art, such as, for example, water or other solvents, solubilizing agents and emulsifiers, such as ethyl

alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor, peach, almond and sesame oils), glycerol, tetrahydrofuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof.

Suspensions, in addition to the active compounds, may contain suspending agents as, for example, ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth, and mixtures thereof.

The ointments, pastes, creams and gels may contain, in addition to an active compound of this invention, excipients, such as animal and vegetable fats, oils, waxes, paraffins, starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones, bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

The term "cream" is art recognized and is intended to include semi-solid emulsion systems which contain both an oil and water. Oil in water creams are water miscible and are well absorbed into the skin, Aqueous Cream BP. Water in oil (oily) creams are immiscible with water and, therefore, more difficult to remove from the skin. These creams are emollients, lubricate and moisturize, e.g., Oily Cream BP. Both systems require the addition of either a natural or a synthetic surfactant or emulsifier.

The term "ointment" is art recognized and is intended to include those systems which have oil or grease as their continuous phase. Ointments are semi-solid anhydrous substances and are occlusive, emollient and protective. Ointments restrict transepidermal water loss and are therefore hydrating and moisturizing. Ointments can be divided into two main groups- fatty, e.g., White soft paraffin (petrolatum, Vaseline), and water soluble, e.g., Macrogol (polyethylene glycol) Ointment BP.

The term "lotion" is art recognized and is intended to include those solutions typically used in dermatological applications.

The term "gel" is art recognized and is intended to include semi-solid permutations gelled with high molecular weight polymers, e.g., carboxypolymethylene (Carbomer BP) or methylcellulose, and can be regarded as semi-plastic aqueous lotions. They are typically non-greasy, water miscible, easy to apply and wash off, and are especially suitable for treating hairy parts of the body.

In a one embodiment, liposomes are used to deliver the energy activatable material to the follicle matrix. Liposomes provide site-specific transdermal delivery to the follicle matrix. In this embodiment, the energy activatable material is microencapsulated within the liposome and topically applied to the epidermis of the skin.

5 As noted above, the carrier according to the present invention involves encapsulating the effective amount of energy activatable material within a specific liposome to provide for efficient transdermal delivery of the energy activatable material through the layers of the skin. These liposomal compositions are topically applied to the skin and deliver the encapsulated energy activatable material to the follicle region  
10 including the sebaceous gland and infundibulum. Following delivery of the energy activatable material, irradiation results in highly specific targeting of the follicle matrix and destruction of oils, dirt, bacteria, mites, or viruses within the infected area.

Liposomes are microscopic spherical membrane-enclosed vesicles or sacks (0.5-500  $\mu\text{m}$  in diameter) made artificially in the laboratory using a variety of methods.

15 Within the scope of the present invention, the liposomes should be non-toxic to living cells and they should deliver the contents, in this case an energy activatable material, into the follicle and immediately surrounding tissue. The liposomes according to the present invention may be of various sizes and may comprise either one or several membrane layers separating the internal and external compartments.

20 The liposomes may be made from natural and synthetic phospholipids, and glycolipids and other lipids and lipid congeners; cholesterol, cholesterol derivatives and other cholesterol congeners; charged species which impart a net charge to the membrane; reactive species which can react after liposome formation to link additional molecules to the lysome membrane; and other lipid soluble compounds which have chemical or  
25 biological activities.

A general discussion of the liposomes and liposome technology can be found in an article entitled, "Liposomes" by Marc J. Ostro, published in *SCIENTIFIC AMERICAN*, January 1987, Vol. 256, pp. 102-111 and in a three volume work entitled, "Liposome Technology" edited by G. Gregorriadis, 1984, published by CRC press, Boca Raton, Fla.  
30 the pertinent portions of which are incorporated herein by reference.

Figure 1 illustrates multiple hair shafts 10 (vellus) projecting below the epidermis region 12 of the skin and into the dermis 14 region. Each shaft 10 extends down the

follicle 16. The follicle includes a sebaceous gland 20 and which at the anagen stage of the hair cycle further includes a papilla 18. The papilla 18 is supplied with small blood vessels (not shown) that provide the growing hair with nourishment. The follicle 16 includes the pore opening 22 and the infundibulum 24, shown with a plug 26 of dead cells, oils, bacteria and/or viruses. Topical application of an energy activatable material 28 penetrates the pore opening 22 and infundibulum 24 and into the sebaceous gland 20 as shown in Figures 1 and 2.

In order to assure removal of plug 26, modification of pore opening 22, modification of the infundibulum 24, and/or modification of the sebaceous gland 20, use of a light source, e.g., a laser, having sufficient energy and depth of penetration is required. Figure 3 demonstrates how an operator (not shown) will position the energy source 30, e.g., a laser, over a hair follicle 16 such that an optimum location for aiming the light pulse to strike the energy activatable material 28 about the plug 26, sebaceous gland 20, infundibulum 24 and/or pore opening 22 is obtained. The energy source 30 can be moved across the skin surface in any direction 32 by the operator, thereby effectively irradiating multiple follicles 16 multiple times. The process can be repeated until the desired effect(s) are achieved.

Figures 4a and 4b demonstrate the effect(s) of the presently described treatment on the infundibulum 24. Figure 4a depicts infundibulum 24 prior to treatment with an energy activatable material 28 and stimulation with an energy source 30. Figure 4b depicts the same infundibulum 24 post treatment whereby the shape of the infundibulum 24 and pore opening 22 have been modified.

Figures 5a and 5b demonstrate the effect(s) of the presently described treatment on the sebaceous gland 20. Figure 5a depicts the sebaceous gland 20 prior to treatment with an energy activatable material 28 and stimulation with an energy source 30. Figure 5b depicts the same sebaceous gland 20 post treatment, whereby the size of sebaceous gland 20 has been decreased.

Figures 6a and 6b demonstrate the effect(s) of the presently described treatment on a plugged pore 26. Figure 6a depicts the plug 26 prior to treatment with an energy activatable material 28 and stimulation with an energy source 30. Figure 6b depicts the same region of the infundibulum 24 post treatment, whereby the plug 26 has been treated such that unwanted material(s) has been removed from infundibulum 24.

Figures 7a and 7b further demonstrate the effect(s) of the presently described treatment on a plugged pore 26, infundibulum 24, pore opening 22, and sebaceous gland 20. Figure 7a depicts the skin area prior to treatment with an energy activatable material 28 and stimulation with an energy source 30. Figure 7b depicts the same region of the skin post treatment, whereby the plug 26 has been treated such that unwanted material(s) has been removed from infundibulum 24 and the infundibulum 24, pore opening 22 and sebaceous gland 20 have been modified.

Stimulation of the energy activatable material 28 will cause activation to occur, e.g., photothermolysis and/or photochemical reactions, to disrupt the trapped cells, sebum, bacteria, mites, etc. located in the sebaceous gland 20 and/or the infundibulum 24. An advantage of this process is that only tissue having energy activatable material will undergo photothermal or photochemical reactions. Surrounding tissue which does not include energy activatable material will not be adversely affected by this treatment.

Natural chromophores present in sebaceous follicles or follicular plugs are not sufficiently distinct from other chromophores of the dermis and epidermis to allow specific absorption. However, the infundibulum and sebaceous glands are directly accessible from the skin surface through a "pore" (the follicle opening), which allows topically-applied substances, such as energy activatable materials, to enter these structures. Therefore, energy activatable materials or particle-suspensions can be used to provide high, local, and specific absorption after uptake into the infundibulum and/or sebaceous gland.

Energy activatable materials which enter the sebaceous follicles, such as methylene blue (a lipophilic, cationic, FDA-approved dye is taken up into human sebaceous follicles, and distributed over time into the sebaceous glands), can be used to target either the infundibula, or the sebaceous glands depending on time after application, or both.

Topically-applied energy activatable materials initially enter the infundibulum and later distribute to the sebaceous glands. It is possible to actively drive those materials or chromophoric particles into the follicles by massage, pressure, ultrasound, or iontophoresis, after topically applying the chromophore to the skin surface. Methylene blue, for example, can be rapidly driven into sebaceous follicles and eccrine sweat ducts by iontophoresis. Wiping the surface with or without a solvent after delivery into the



follicles, can be used to remove residual material from the skin surface. Thus, after appropriate application and wiping, the energy activatable material, e.g., a chromophore, can be preferentially located in follicles, within the infundibula or the infundibula and sebaceous glands.

5           A preferred method of delivery for administering an energy activatable material described throughout this application is by iontophoresis. Iontophoresis may be generally described as a method of transdermally introducing medicament ions, zwitterions, molecules, e.g., an energy activatable material, preferably methylene blue, into a the body. The iontophoresis process utilizes the current developed by an electric field to  
10       drive energy activatable ions through the skin, or other biological surface, and into the body. The iontophoresis process has been found to be particularly useful in transdermal administration of energy activatable materials, such as many of the compounds discussed herein , and in particular, methylene blue.

          For example, and advantage of iontophoresis is the introduction of energy  
15       activatable materials directly into a patient's tissues, e.g., the infundibulum and/or sebaceous gland, without the need for a needle-based injection, which typically causes pain and may create a risk of infection. Iontophoretic delivery of energy activatable materials is also advantageous because this delivery system avoids premature metabolism of the material that can typically occur when a drugs is taken orally. Premature  
20       metabolism is often a concern where oral drugs are used to treat acne because the medicament ions derived are absorbed into the blood stream from the digestive system. The blood containing the medicament ions then percolates through the liver, where the medicament ions may be prematurely metabolized, before the medicament ions arrive at the target tissue. Thus, a substantial amount of the medicament ions derived from an  
25       orally administered drug may be metabolically inactivated before the medicament ions have a chance to pharmacologically act in the body.

          A typical iontophoresis device includes two electrodes such as those devices produced by Iomed, Inc. (Salt Lake City, Utah, US). One of the electrodes is often characterized as an "active" electrode, and the other electrode is often characterized as a  
30       "return" electrode. Also, one of the electrodes is a positively charged anode and the other electrode is a negatively charged cathode. Both electrodes are in intimate electrical contact with the skin or other biological surface of the body, which may be a human body

or another type of body, such as an animal body. Application of electric current to the active electrode drives the energy activatable material, such as the methylene blue, from the active electrode into the body. The other electrode, the return electrode, closes the electrical circuit to permit current flow through the active electrode and through the body.

5 In general, an energy activatable material is applied topically to the area to be treated as a solution or suspension. Typical solutions are aqueous based solutions, e.g., water, which can contain low molecular weight alcohols, e.g., ethanol, isopropanol, butanol. Penetration of the energy activatable material into the infundibulum and/or sebaceous gland is facilitated by iontophoretic application. Generally, the site of  
10 treatment and a major muscle site are cleansed with an alcoholic solution. A dispersive pad is applied over the major muscle at least 6 inches from the drug electrode site. A hydrated drug electrode pad is applied to the cleansed treatment site and appropriate lead clips are attached to the pads. Typically, the iontophoresis current is between about 0.1 to 40 mA/min, with a current of about 2 to 4 mA. The treatment period is generally  
15 between about 10 and 20 minutes and the treatment site can be from about 1 centimeter to about 11 centimeters in diameter. Those skilled in the art can identify those parameters necessary to administer the activatable material dependent upon the age, sex, weight, and skin condition of the individual. Energy activatable material concentrations are greatest in the infundibulum, eccrine ducts and sebaceous glands. Consequently, these structures  
20 are most affected by subsequent laser treatment. Figure 8 depicts methylene blue which has been iontophoretically administered into the sebaceous glands and/or infundibulum of an individual.

As used herein, the term "iontophoresis device" refers generally to an electrically assisted device or apparatus suitable for the transdermal iontophoretic delivery of  
25 therapeutic levels of an energy activatable material to a mammal. Such iontophoresis devices are well known in the art and are also referred to as "iontophoretic delivery devices" or "electrotransport devices."

Iontophoresis devices and methods for using these devices in conjunction with the present invention are described, for example, in the following U.S. patent documents, the  
30 disclosures of which are incorporated herein by reference:

U.S. Pat. Nos. 3,991,755; 4,141,359; 4,250,878; 4,395,545; 4,744,787; 4,747,819;  
4,927,408; 5,080,646; 5,084,006; 5,125,894; 5,135,477; 5,135,480; 5,147,296; 5,147,297;

5,158,537; 5,162,042; 5,162,043; 5,167,616; 5,169,382; 5,169,383; 5,415,628; 5,203,768;  
5,207,752; 5,221,254; 5,232,438; 5,234,992; 5,240,995; 5,246,417; 5,288,389; 5,298,017;  
5,310,404; 5,312,326; 5,314,502; 5,320,598; 5,322,502; 5,326,341; 5,344,394; 5,374,242;  
5,380,271; 5,385,543; 5,387,189; 5,395,310; 5,403,275; 5,405,317; 5,415,628; 5,423,739;  
5,443,442; 5,445,606; 5,445,609; 5,464,387; 5,466,217; 4,950,229; 5,246,418;  
5,256,137; 5,284,471; 5,302,172; 5,306,235; 5,310,403; 5,320,597; 5,458,569; 5,498,235;  
4,557,723; 4,713,050; 4,865,582; 4,752,285; 5,087,242; 5,236,412; 5,281,287.

Either photothermal (i.e. using principles of selective photothermolysis) or photochemical (i.e., using principles of photodynamic therapy) mechanisms are utilized to affect the target structures, as a treatment to prevent sebaceous gland disorders, such as acne lesions, from forming. Methylene blue (MB) and many other light sensitive chromophores are potent photodynamic photosensitizers and can also be used as photothermal sensitizers. The red absorption maximum of methylene blue around 660 nm provides strong absorption for either mechanism. Another strong candidate dye is indocyanine green (ICG) (Cardiogreen<sup>®</sup>, Becton-Dickenson), which has very poor photodynamic activity but is an excellent photothermal chromophore. Indocyanine green is a zwitterion (neutral, highly polar molecule) which tends to bind strongly to proteins and is well suited for targeting the infundibulum by photothermal mechanisms. ICG absorbs maximally near 800 nm, a wavelength well suited for diode, Alexandrite lasers, and other light sources. For selective photothermolysis, pulses of intense red or near-infrared light in the ms time domain at the appropriate wavelength region should be delivered, for example using a pulsed dye laser, diode laser arrays, other pulsed or scanned lasers, or filtered flashlamp sources to deliver fluences in excess of 1 J/cm<sup>2</sup> per pulse. For photodynamic effects, lower average irradiance exposures given over longer exposure time would be appropriate for example approximately 10-100 mW/cm<sup>2</sup> delivered for about 100-2000 seconds (total fluence, 1-200 J/cm<sup>2</sup>). For photodynamic effect, light sources such as light-emitting diodes, incandescent lamps, xenon arc lamps, lasers or sunlight can be used.

In order to form and retain a plug within the infundibulum, there must be a constriction along the outflow tract. As material including sebum, cells, or bacteria accumulate and are concentrated onto the plug, walls of the infundibulum are dilated until the middle or lower part of the infundibulum is larger in diameter than its outlet (the

surface pore). If the outlet diameter can be increased, the plug is more likely to be expelled and pressure within the sebaceous follicle decreased before rupture can occur. The upper region of the infundibulum is also the source of follicular neck cells which shed into the infundibulum and add to the plug. For these reasons, the walls of the upper portion of the infundibulum and especially its pore at the skin surface are the primary target for energy activatable material-assisted sebaceous gland disorder treatment, e.g. acne treatment. In a manner conceptually similar to laser skin "resurfacing", the shape and size of the infundibulum and its outlet pore can be affected by energy activatable material-assisted photothermal or photochemical treatment. The dermis immediately surrounding sebaceous follicles, is largely responsible for maintaining shape of the infundibulum, and should be altered to produce a permanent affect. By using pulses in the ms time domain, there is time for thermal conduction from energy activatable material in the infundibulum, to the wall and immediately-surrounding dermal collagen of the infundibulum. Photothermal mechanisms are preferred because permanent changes are known to be induced in the dermis.

The invention is further illustrated by the following examples which in no way should be construed as being further limiting. The contents of all references, pending patent applications and published patent applications, cited throughout this application, including those referenced in the background section, are hereby incorporated by reference. It should be understood that the models used throughout the examples are accepted models and that the demonstration of efficacy in these models is predictive of efficacy in humans.

## EXEMPLIFICATION

Fresh, in-vitro human sebaceous skin samples were used. Dye solutions and particle suspensions were applied to the samples at different concentration and in various vehicles, followed by localization of the dye by frozen sectioning and light microscopy. A number of FDA-approved laser sensitive dyes were examined and found that methylene blue and several others rapidly enter the infundibulum. Methylene blue proceeded to deeply and selectively stain the sebaceous glands, requiring several hours to do so. Apparently, almost any dye or suspension can be delivered to the upper infundibulum by direct solvent flow into the pore. Optimization of the concentration and

solvent for MB and ICG can be determined by one skilled in the art. The effect of iontophoresis of MB in vitro should increase rate of uptake by at least one order of magnitude. Physical means of increasing dye uptake into the infundibulum, including ultrasonication with a tissue dismembrator at low intensity, and a simple pressure-applicator intended to open the surface pores while providing a pressure gradient in favor of dye uptake is possible.

For MB dye, a 660 nm source is required, preferably a pulsed dye laser operating with at least 1 ms pulse duration. There is essentially no absorption by MB at wavelengths longer than 690 nm, such that ruby and Alexandrite lasers are not useful. Similar in-vitro laser targeting can be performed using ICG in the infundibulum, and C-particle suspension (medical grade India Ink) to indicate that physical means deliver sufficient chromophore into the infundibulum.

## EXPERIMENTALS

### Experiment using methylene blue to stain sebaceous glands in *ex vivo* tissue.

Freshly excised human skin from a face-lift procedure was provided by a plastic surgeon. The skin originated from the periauricular area and the anterior hairline of a middle-aged fair-skinned female. The samples were stored at 4°C overnight. On the day of experiment, the tissue was shaved with a razor and defatted by rubbing the surface with alcohol swabs for 1 minute. After cutting the skin in smaller pieces, the tissue was placed on saline-soaked gauzes. Methylene blue, a cationic hydrophilic dye was dissolved in distilled water, alcohol, and propylene glycol at a concentration of 5% and applied on the surface of the skin in a thick layer at 31°C. After 1 hour, the excess dye was removed with a dry absorbing gauze revealing a lightly stained epidermis with accentuation of the staining in the follicular pores in all specimen. 5 mm-punch biopsies were performed and the samples were processed frozen sections.

Light microscopy of histologic sections showed dense blue staining of the epidermis and of some sebaceous glands and entire hair follicles (Figure 9). There was minimal non-specific staining of the interstitial dermis.

Freshly excised human skin from a face-lift procedure was provided by a plastic surgeon. The skin originated from the periauricular area and the anterior hairline of a middle-aged fair-skinned female. The samples were stored at 4°C overnight. On the day of experiment, the tissue was shaved with a razor and defatted by rubbing the surface with alcohol swabs for 1 minute. After cutting the skin in smaller pieces, the tissue was placed on saline-soaked gauzes. Methylene blue, a cationic hydrophilic dye was dissolved in distilled water, alcohol, and propylene glycol at a concentration of 5% and was mixed in a commercially available aqueous-based lotion (50 µL of dissolved dye in 500 mg of lotion) and applied on the surface of the skin in a thick layer at 31°C. After 1 hour, the excess dye was removed with a dry absorbing gauze revealing a lightly stained epidermis with accentuation of the staining in the follicular pores in all specimen. 5 mm-punch biopsies were performed and the samples were processed frozen sections.

Light microscopy of histologic sections showed dense blue staining of the epidermis and of some sebaceous glands and entire hair follicles (Figure 10). There was minimal non-specific staining of the interstitial dermis.

Methylene blue dye was also administered into the sebaceous glands via Retina Gel® (Ortho Pharmaceuticals) as the carrier vehicle. Typically, a sufficient amount of methylene blue (50 µL of dissolved dye in 500 mg of gel) was combined with hydroxypropyl cellulose, butylated hydroxytoluene and alcohol and applied to the epidermis. Penetration of the methylene blue dye into the sebaceous glands of freshly excised human skin was noted via light microscopy as described above.

## EQUIVALENTS

Those skilled in the art will recognize, or be able to ascertain, using no more than routine experimentation, many equivalents to specific embodiments of the invention described specifically herein. Such equivalents are intended to be encompassed in the scope of the following claims.

What is claimed is:

1. A method for treating a sebaceous gland disorder comprising the steps of

a) topically applying an energy activatable material to a section of skin afflicted with a sebaceous gland disorder, wherein said material is activated by energy which penetrates outer layers of epidermis,

b) causing a sufficient amount of said material to infiltrate into spaces in said skin; and

c) exposing said section of skin to energy sufficient to cause said material to become photochemically or photothermally activated, thereby treating said sebaceous gland disorder.

2. The method of claim 1, wherein said energy activatable material is selected from the group consisting of chromophore containing groups, carbon particles and iron oxides.

3. The method of claim 2, wherein said chromophore containing group is methylene blue.

4. The method of claim 2, wherein said chromophore containing group is a laser sensitive material.

5. The method of claim 4, wherein said laser sensitive material is methylene blue.

6. The method of claim 1, wherein said energy activatable material is suspended in a pharmaceutical carrier.

7. The method of claim 6, wherein said pharmaceutical carrier is a liposome.

8. The method of claim 6, wherein said pharmaceutical carrier is an oil.

9. The method of claim 8, wherein said oil is baby oil.

5 10. The method of claim 1, wherein said energy activatable material penetrates said skin via a pilosebaceous unit.

11. The method of claim 1, wherein said treatment modifies the opening to the infundibulum.

10

12. The method of claim 11, wherein said opening is opened.

13. The method of claim 1, wherein said energy activatable material penetrates a sebaceous gland.

15

14. The method of claim 13, wherein said sebaceous gland is modified.

15. The method of claim 1, wherein said sebaceous gland disorder is acne vulgaris, acne rosacea, or sebaceous gland hyperplasia.

20

16. The method of claim 1, wherein ultrasound is utilized to force said energy activatable material into said spaces.

17. The method of claim 1, wherein said energy is from a pulsed laser dye.

25

18. The method of claim 1, wherein said energy is from a diode laser array.

19. The method of claim 1, wherein said spaces in said skin comprise spaces in hair ducts in said skin not occupied by hair.

30

20. The method of claim 1, wherein said spaces in said skin comprises space within sebaceous glands.



21. The method of claim 1, wherein said spaces in said skin comprise space adjacent to sebaceous glands.

22. A method for modifying the opening to the infundibulum comprising the steps of:

a) topically applying an energy activatable material to the opening to the infundibulum, wherein said material is activated by energy which penetrates outer layers of epidermis,

b) causing a sufficient amount of said material to infiltrate into spaces about said infundibulum; and

c) exposing said section of skin with sufficient energy to cause said material to become photochemically or photothermally activated, thereby modifying said opening to the infundibulum.

23. A method for modifying the pilosebaceous unit comprising the steps of:

a) topically applying an energy activatable material to the pilosebaceous unit, wherein said material is activated by energy which penetrates outer layers of epidermis,

b) causing a sufficient amount of said material to infiltrate the pilosebaceous unit; and

c) exposing said section of skin with sufficient energy to cause said material to become photochemically or photothermally activated, thereby modifying the pilosebaceous unit.

24. A method for treating a sebaceous gland disorder comprising the steps of

a) topically applying an energy activatable material to a section of skin afflicted with a sebaceous gland disorder, wherein said material is activated by energy which penetrates outer layers of epidermis,

b) iontophoretically causing a sufficient amount of said material to infiltrate into spaces in said skin; and

c) exposing said section of skin to energy sufficient to cause said material to become photochemically or photothermally activated, thereby treating said sebaceous gland disorder.

5           25.    The method of claim 24, wherein said energy activatable material is selected from the group consisting of chromophore containing groups, carbon particles and iron oxides.

10           26.    The method of claim 24, wherein said chromophore containing group is methylene blue.

          27.    The method of claim 24, wherein said chromophore containing group is a laser sensitive material.

15           28.    The method of claim 27, wherein said laser sensitive material is methylene blue.

          29.    The method of claim 24, wherein said energy activatable material is suspended in a pharmaceutical carrier.

20           30.    A method for modifying the opening to the infundibulum comprising the steps of:

          a)    topically applying an energy activatable material to the opening to the infundibulum, wherein said material is activated by energy which penetrates outer  
25    layers of epidermis,

          b)    iontophoretically causing a sufficient amount of said material to infiltrate into spaces about said infundibulum; and

          c)    exposing said section of skin with sufficient energy to cause said material to become photochemically or photothermally activated, thereby modifying said  
30    opening to the infundibulum.

          31.    A method for modifying the pilosebaceous unit comprising the steps of:

a) topically applying an energy activatable material to the pilosebaceous unit, wherein said material is activated by energy which penetrates outer layers of epidermis,

b) iontophoretically causing a sufficient amount of said material to  
5 infiltrate the pilosebaceous unit; and

c) exposing said section of skin with sufficient energy to cause said material to become photochemically or photothermally activated, thereby modifying the pilosebaceous unit.

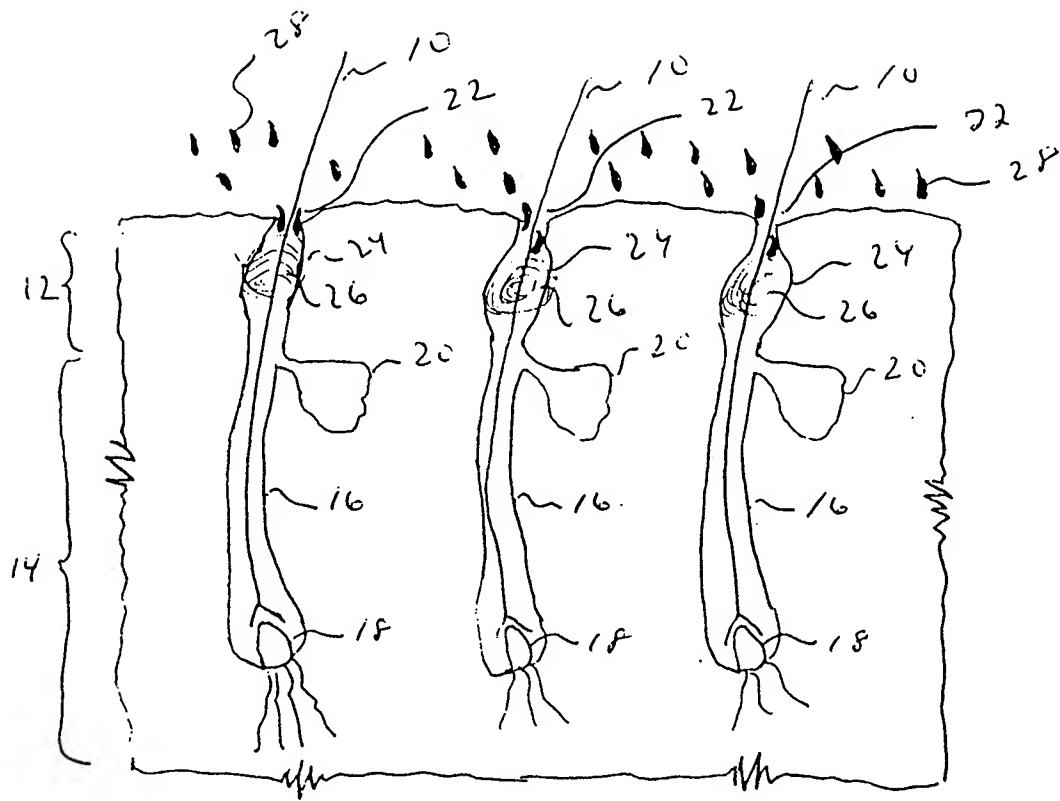


FIG 1

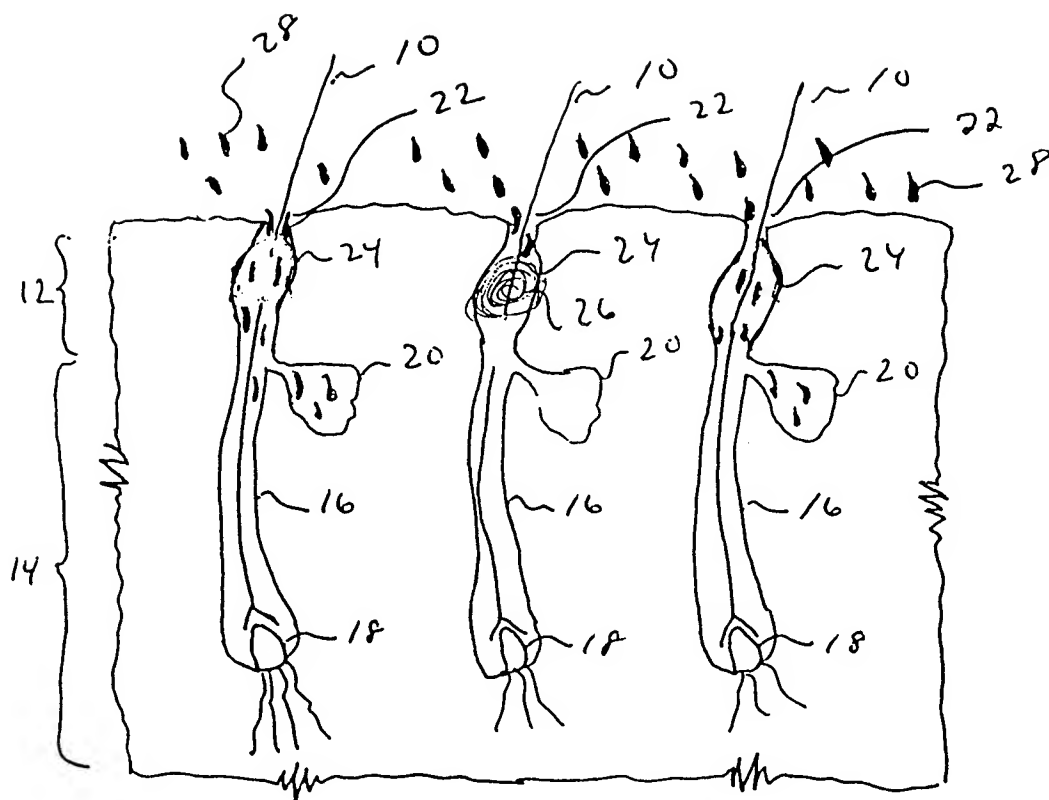


FIG 2

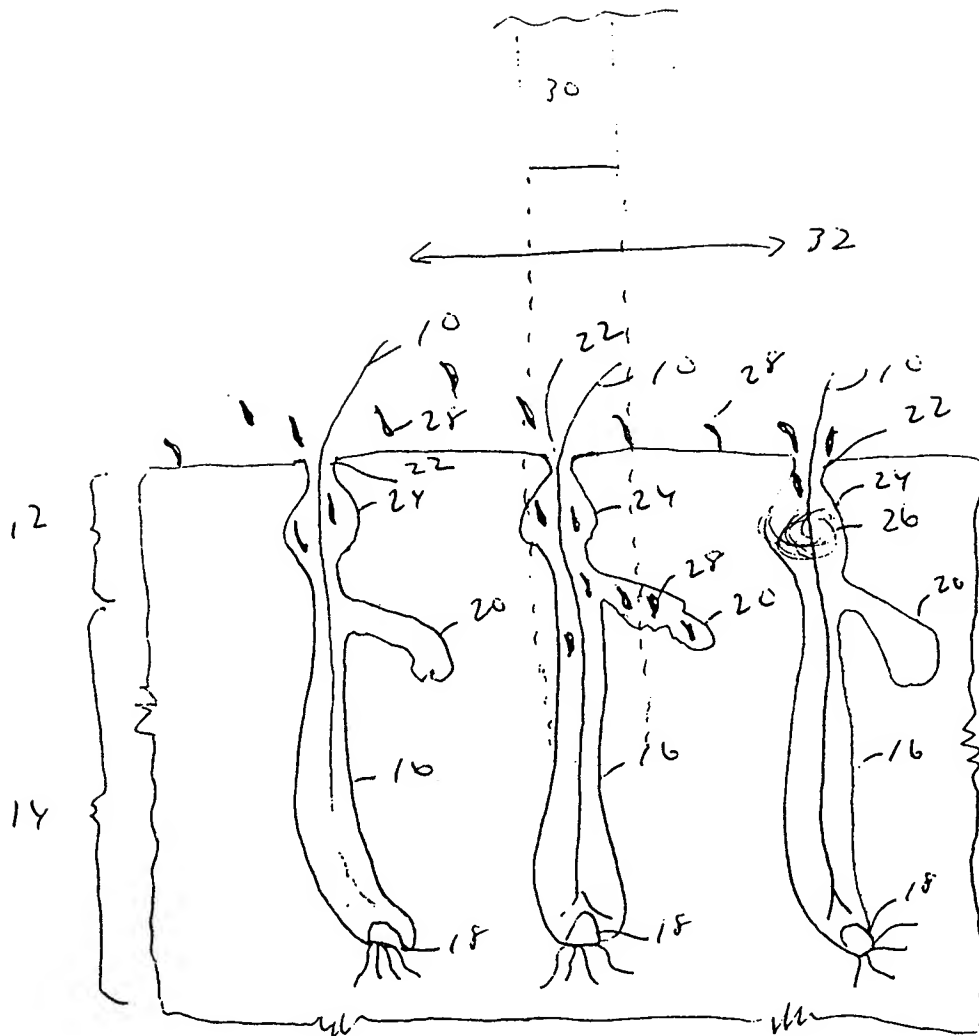


Fig 3

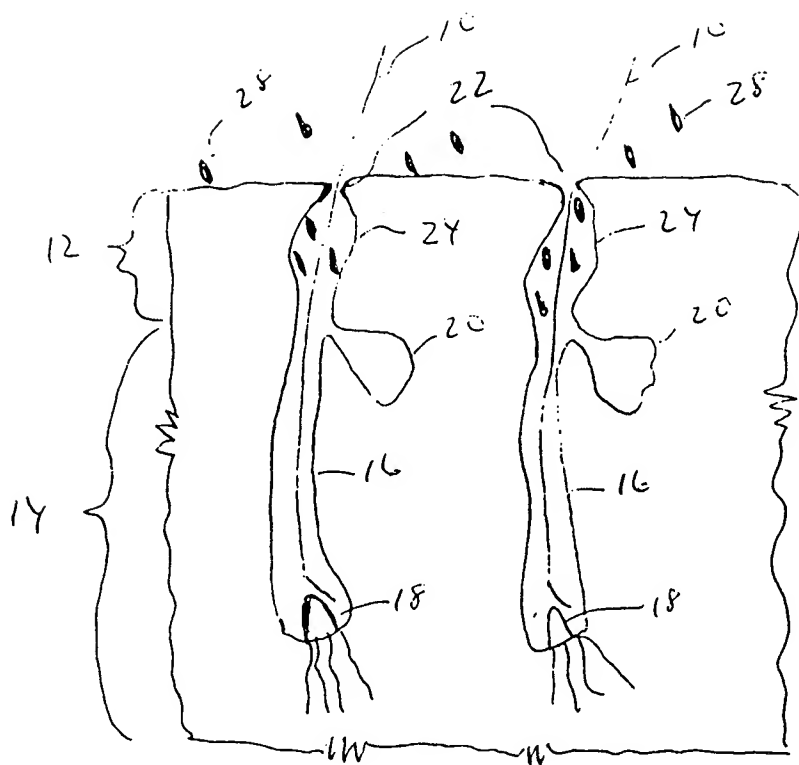


Fig. 4A

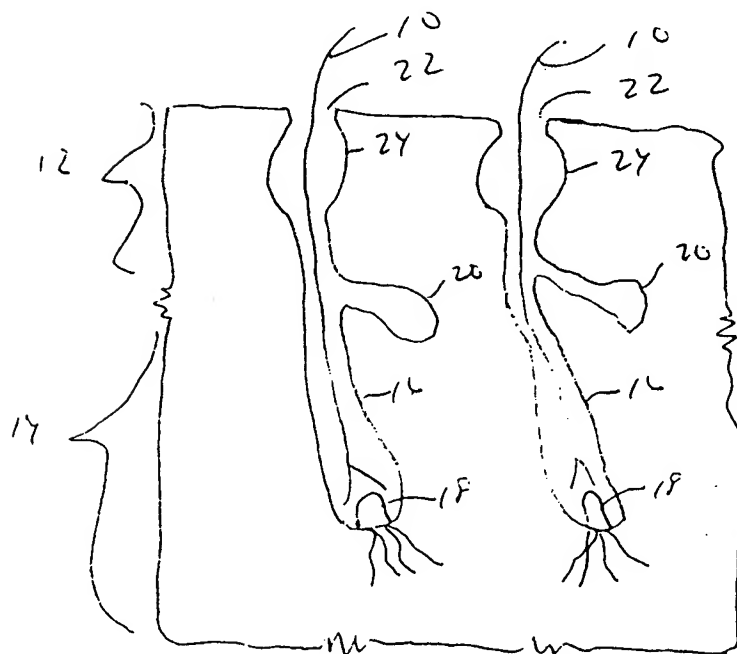


Fig. 4B

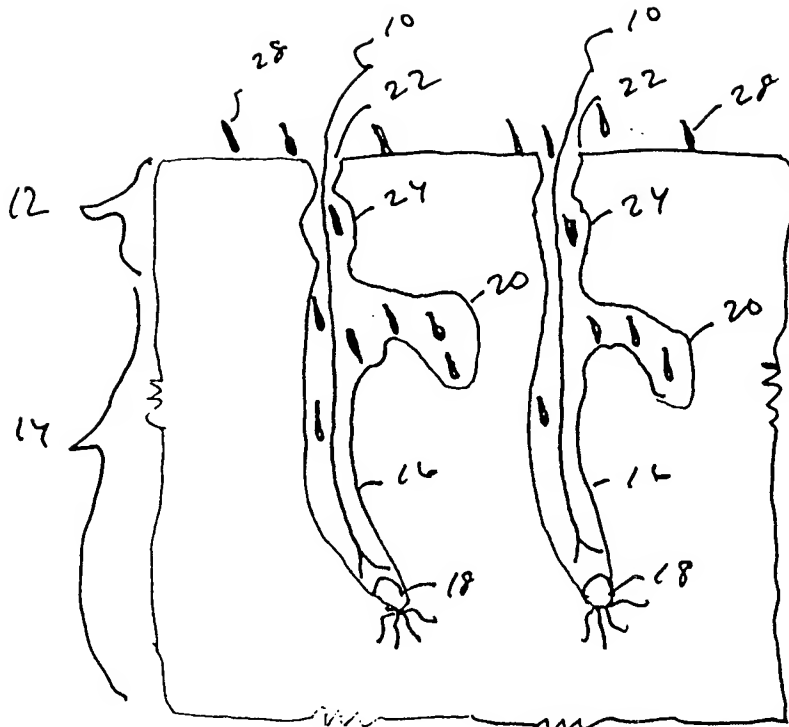


Fig 5A

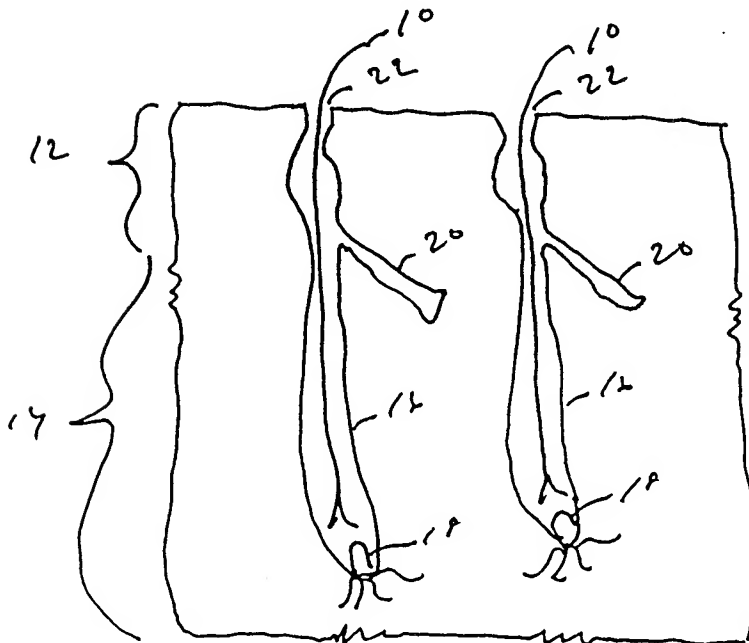


Fig 5B



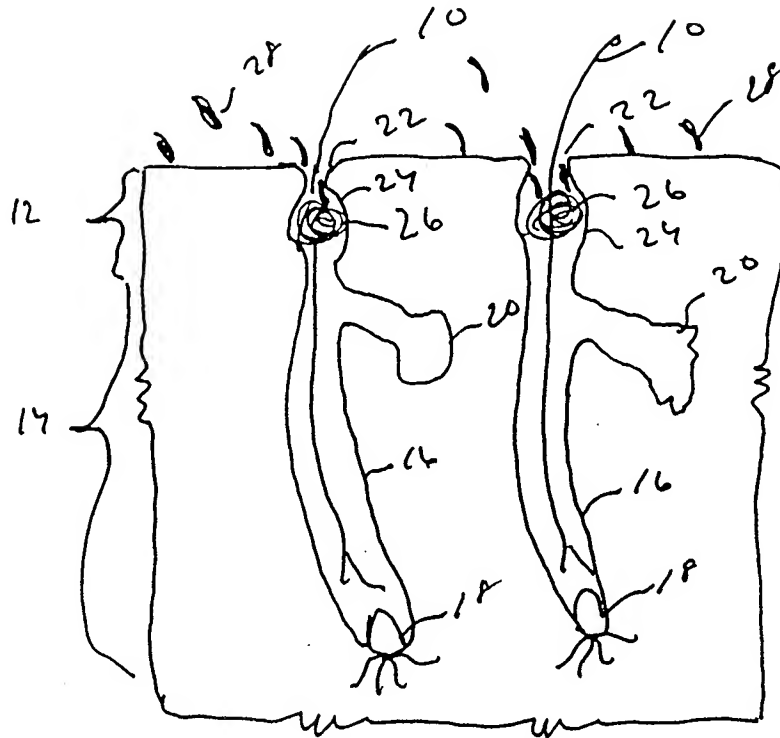


Fig 6A

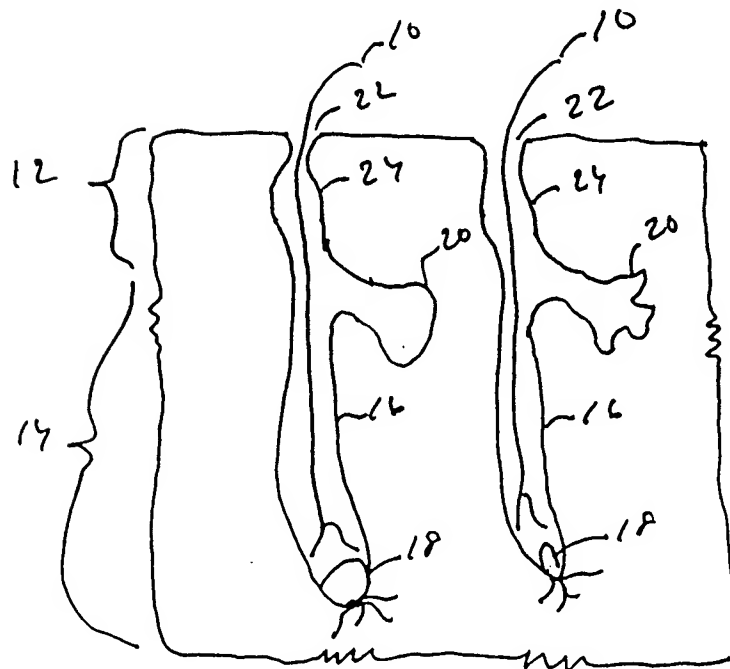


Fig 6B

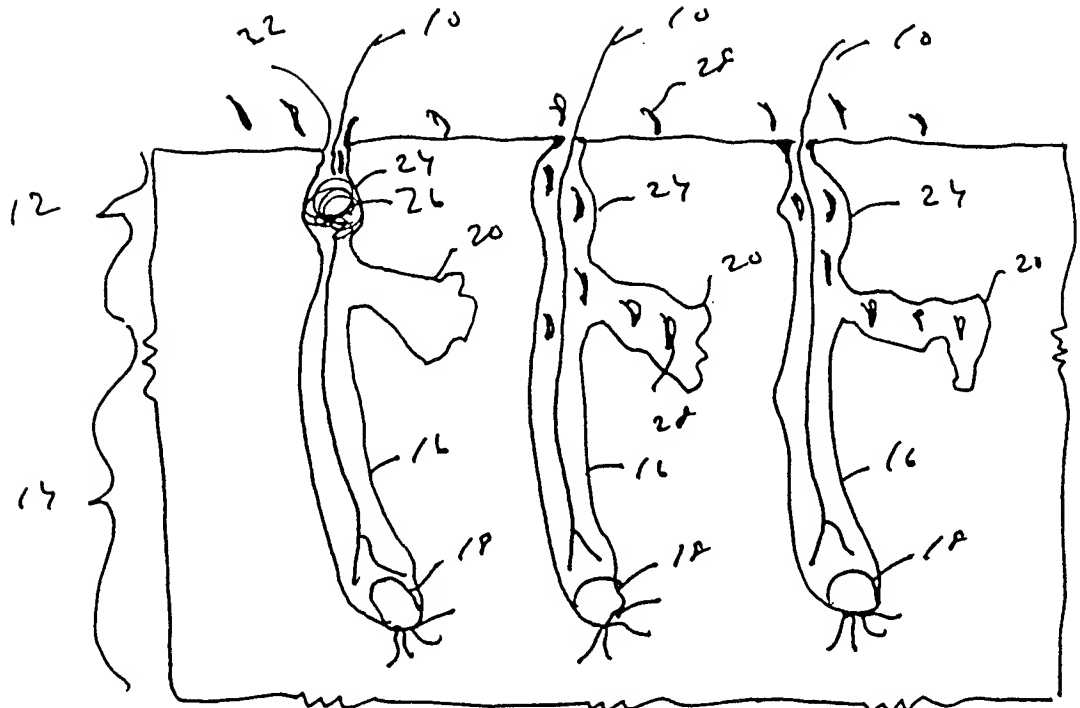


Fig. 7A

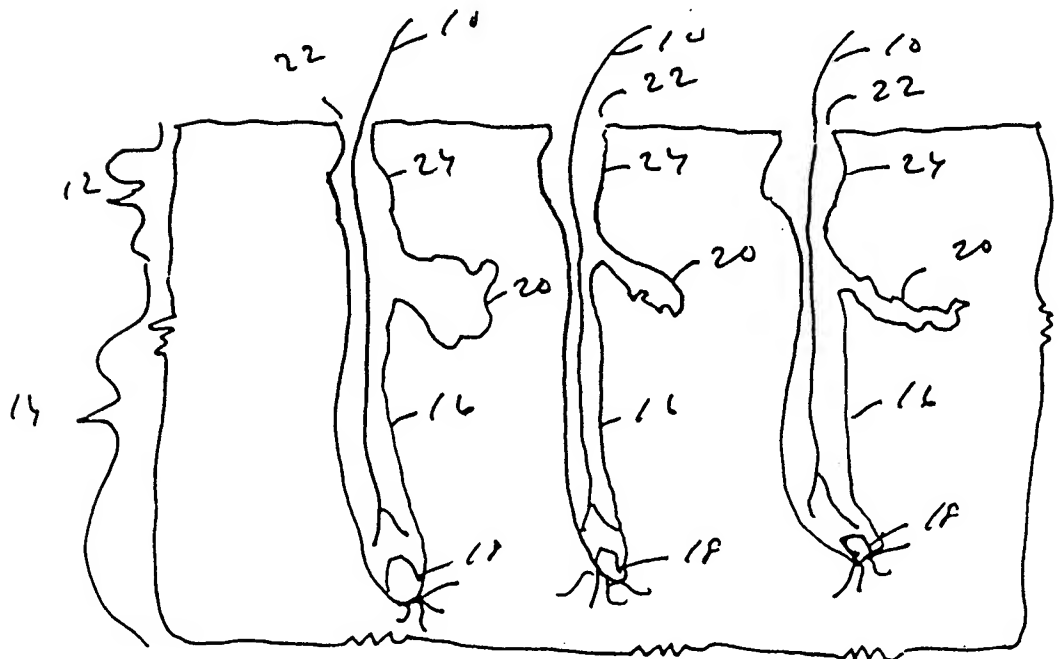


Fig. 7B

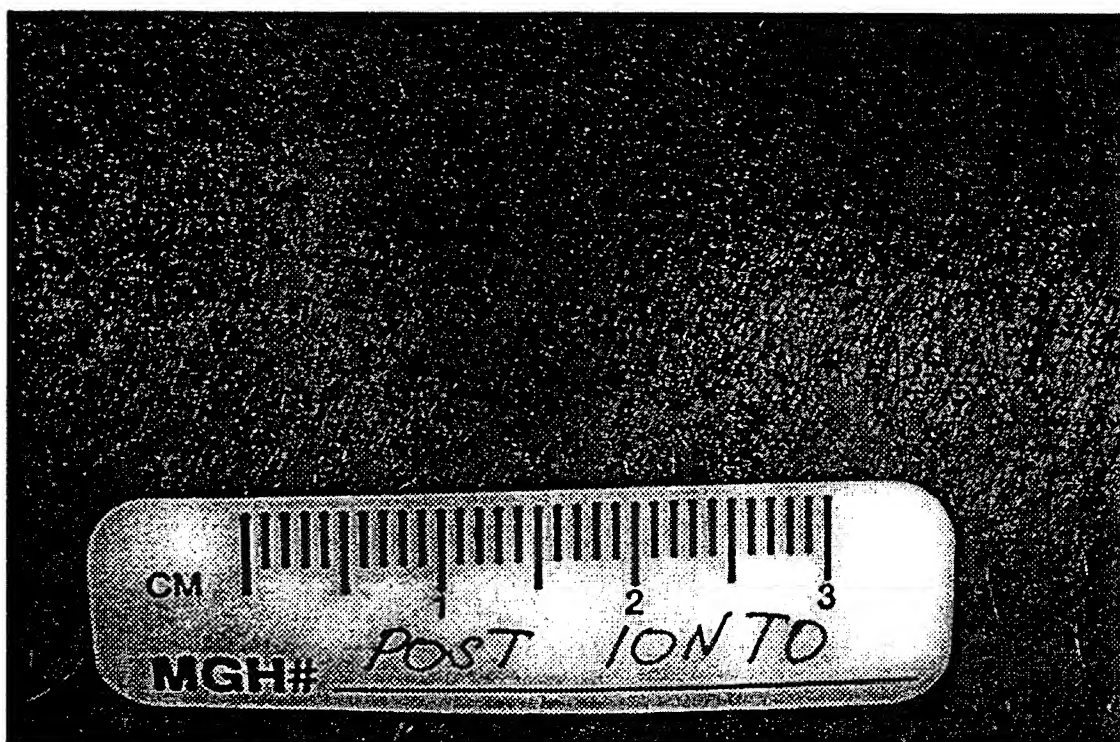


FIG. 8

Figure 9 Blue staining of the sebaceous gland and hair follicle by methylene blue in an aqueous based lotion



Figure 10 Blue staining of the sebaceous gland and hair follicle by methylene blue in an aqueous based lotion

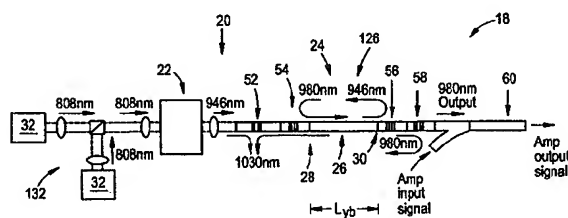




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b> <b>H01S 3/067, 3/094, 3/16</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/41278</b> <b>(43) International Publication Date:</b> 13 July 2000 (13.07.00)
<b>(21) International Application Number:</b> PCT/US99/29629 <b>(22) International Filing Date:</b> 14 December 1999 (14.12.99)  <b>(30) Priority Data:</b> 60/115,229                      8 January 1999 (08.01.99)                      US  <b>(71) Applicant:</b> CORNING INCORPORATED [US/US]; 1 Riverfront Plaza, Corning, NY 14831 (US).  <b>(72) Inventor:</b> ZENTENO, Luis, A.; 38 Katie Lane, Painted Post, NY 14870 (US).  <b>(74) Agent:</b> AGON, Juliana; Patent Department, SP TI 3-1, Corning Incorporated, Corning, NY 14831 (US).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

**(54) Title:** SEMICONDUCTOR-SOLID STATE LASER OPTICAL WAVEGUIDE PUMP DEVICE AND METHOD

**(57) Abstract**

The invention includes a solid state laser (22) which outputs wavelength emission  $\lambda_{ss}$  centered about 946 nm, combined with a lasering waveguide (24) which includes a Yb doped optical waveguide (26) such that when the  $\lambda_{ss}$  output is inputted into the lasering waveguide (24) the lasering waveguide produces a wavelength emission  $\lambda_y$  centered about 980 nm. The invention further includes the utilization of pump light with optical waveguide amplifying device.

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BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
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CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
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CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
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CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
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**SEMICONDUCTOR-SOLID STATE LASER OPTICAL WAVEGUIDE PUMP  
DEVICE AND METHOD**

**CROSS-REFERENCE TO RELATED APPLICATIONS**

5           This application claims priority to U.S. Provisional patent Application Serial No. 60/115,229, filed on January 8, 1999, the content of which is relied upon and incorporated herein by reference in its entirety.

**BACKGROUND OF THE INVENTION**

10           The present invention relates generally to optical waveguide devices, semiconductor lasers, solid state lasers, and particularly to the utilization of lasers to pump optical waveguide amplifiers.

          Optical amplifiers and lasers are important components used in optical fiber telecommunications systems. Optical signals transmitted in optical fibers tend to  
15       weaken as they travel along the optical fibers. Optical amplifiers provide an economic means of amplifying such weakened optical signals while maintaining the optical nature of the signal.

          Erbium doped optical fiber amplifiers have become the dominant means of amplifying optical signals in the 1550 nm optical telecommunications window. Such  
20       erbium doped optical fiber amplifiers are normally directly pumped with 980 nm and/or 1480 nm semiconductor pump lasers. With such an amplifier-pump system, electrical energy applied to the 980 nm (1480 nm) semiconductor pump laser produces 980 nm (1480 nm) photons which are coupled through an optical fiber pigtail into the erbium doped optical fiber. The 980 nm and/or 1480 nm pump light excites/energizes the



erbium ions in the erbium doped optical fiber so that 1550 nm optical telecommunications signals are amplified by the excited/energized erbium ions. Such direct optical pumping of optical amplifiers with semiconductor produced photons has become the standard in the optical telecommunications industry because of reliability and related use requirements, for example compact space utilization. But, in addition to economic expense problems, such direct semiconductor pump lasers pose problems in terms of already reaching maximum optical output power limitations while the development of optical amplifiers has continued to require higher and higher pump power input requirements. It appears that the commercially available maximum reliable output power of 980 nm semiconductor laser pumps may plateau in the 300 mW output power range while the input pump power requirements of optical amplifiers continue to climb. Semiconductor laser research and development continue to strive towards improving the structure and performance of 980 nm semiconductor laser pumps in an effort to try to meet the needs of optical amplifiers.

The optical amplifier industry needs a pump laser technology that is able to meet its ever increasing optical power demands.

### **SUMMARY OF THE INVENTION**

One aspect of the present invention is an optical waveguide device which includes a solid state laser which outputs wavelength emission  $\lambda_{ss}$  centered about 946 nm, combined with a lasing waveguide which includes a Yb doped optical waveguide such that when the  $\lambda_{ss}$  output is inputted into the lasing waveguide the lasing waveguide produces a wavelength emission  $\lambda_y$  centered about 980 nm.

In another aspect, the present invention includes a method of producing 980 nm optical amplifier pump wavelength light which includes providing a first laser for producing an emission  $\lambda_1$ , inputting the produced emission  $\lambda_1$  into a second laser for producing an emission  $\lambda_2$ , producing an emission  $\lambda_2$ , inputting the produced emission  $\lambda_2$  into a third laser for producing an emission  $\lambda_3$  centered about the 980 nm optical amplifier pump wavelength.

In a further aspect the invention includes an optical amplifier device which includes at least one semiconductor laser which produces an emission  $\lambda_1$ , centered about 808 nm, a first solid state laser which is optically pumped by the semiconductor

laser such that it produces an emission  $\lambda_2$  centered about 946 nm, a second solid state laser which is optically pumped by the first solid state laser such that it produces an emission  $\lambda_3$  centered about 980 nm, and an optical amplifier waveguide for amplifying an optical transmission signal wherein the optical amplifier is optically pumped by the second solid state laser.

The invention further includes a method of amplifying an optical transmission signal which comprises the steps of: providing a first laser for producing  $\lambda_1$  light, a second laser for producing  $\lambda_2$  light, and a third laser for producing  $\lambda_3$  light, and an optical amplifier which utilizes  $\lambda_3$  light to amplify an optical signal; pumping the second laser with  $\lambda_1$  light produced by the first laser; pumping the third laser with  $\lambda_2$  light produced by the second laser; and pumping the optical amplifier with  $\lambda_3$  light produced by the third laser.

Additionally, the invention includes a method of making a 980 nm pump for an optical amplifier, with the method including: providing at least one semiconductor laser diode, coupling the semiconductor laser diode into a Nd:YAG laser, and coupling the Nd:YAG laser into a Yb doped optical waveguide fiber laser.

In a further aspect the invention includes an optical amplifier system comprising a single cladding optical waveguide lasing fiber and a multimode pump source.

The invention further comprises a method of making an optical amplifier pump, which includes providing a multimode pump source; providing a single cladding optical waveguide lasing fiber; and indirectly pumping the lasing fiber with the multimode pump source.

Additionally the invention includes the method of amplifying an optical signal  $\lambda_s$ , by providing a multimode light pump source having a wavelength  $\lambda_{mm}$  multimode brightness output; converting the multimode brightness output into a single mode output having a wavelength  $\lambda_{pump}$ ; and inputting the single mode output into an optical amplifier for amplifying an optical signal  $\lambda_s$ .

In a further aspect the invention includes an optical amplifier pump for pumping an optical amplifier with a pump wavelength  $\lambda_{pump}$ , where the pump includes a semiconductor laser which produces a wavelength  $\lambda_{semi}$  and the pump outputs at least 500 mW of light at  $\lambda_{pump}$ .

Additionally the invention includes an optical amplifier pump comprising:  
a semiconductor laser which produces a wavelength  $\lambda_1$  for pumping Nd ions; a plurality  
5 of Nd ions, which when pumped by the wavelength  $\lambda_1$ , produces a wavelength  $\lambda_2$  for  
pumping Yb ions; and a plurality of Yb ions, which when pumped by the wavelength  $\lambda_2$   
produces a wavelength  $\lambda_3$  for pumping Er ions.

In a further aspect the invention includes an optical amplifier pump for pumping  
an optical amplifier which amplifies optical signals in the range of 1560 to 1620 nm (L-  
10 band), which has at least one broad area semiconductor laser; and a neodymium doped  
solid state laser, with solid state laser pumped by the semiconductor laser.

Additionally the invention includes an optical amplifier that comprises  
a semiconductor laser; a solid state laser, the solid state laser pumped by the  
semiconductor laser; and an Er doped optical amplifier fiber, with the Er doped optical  
15 amplifier fiber for amplifying signals in the range of 1560 to 1620 nm and pumped by  
the solid state laser.

In a further aspect the invention includes a method of amplifying a L-band  
optical signal by providing an Er doped optical fiber, pumping a neodymium solid  
state laser with a broad area semiconductor laser, inputting said solid state laser directly  
20 into the Er doped optical fiber, and amplifying a L-band optical signal with the Er  
doped optical fiber.

Additional features and advantages of the invention will be set forth in the  
detailed description which follows, and in part will be readily apparent to those skilled  
in the art from that description or recognized by practicing the invention as described  
25 herein, including the detailed description which follows, the claims, as well as the  
appended drawings.

It is to be understood that both the foregoing general description and the  
following detailed description are merely exemplary of the invention, and are intended  
to provide an overview or framework for understanding the nature and character of the  
30 invention as it is claimed. The accompanying drawings are included to provide a  
further understanding of the invention, and are incorporated in and constitute a part of  
this specification. The drawings illustrate various embodiments of the invention, and

together with the description serve to explain the principles and operation of the invention.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a schematic representation in accordance with the present invention.

FIG. 2 is schematic representation in accordance with the present invention.

FIG. 3 is schematic representation in accordance with the present invention.

FIG. 4 is a graph of output power (milliwatts) at 980nm versus input power (milliwatts) at 946nm.

FIG. 5 is an output spectrum plot of light from a Yb fiber laser.

FIG. 6 is an output spectrum plot of light, which shows three output spectrums from Yb fiber lasers.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. An exemplary embodiment of the present invention is shown in Figure 1. The laser system of the invention is designated generally throughout by reference numeral 20.

In accordance with the invention, the present invention for an optical waveguide device 18 includes a solid state laser 22. Solid state laser 22 outputs a wavelength emission  $\lambda_{ss}$  centered about 946 nm. Solid state laser 22 provides a reliable source for producing a high powered laser light output centered about 946 nm. Preferably solid state laser 22 is a neodymium doped solid state laser.

Solid state laser 22 is preferably a neodymium doped solid state laser, such as the Nd:YAG solid state laser shown in FIGS. 2, that is pumped by two semiconductor laser diodes 32. Preferred semiconductor lasers for pumping the neodymium doped solid state laser are semiconductor lasers that emit light having a wavelength X with X selected from the Nd absorption bands near 880nm(from about 860 to about 900nm), 808nm(from about 780 to about 830nm), 740nm(from about 720 to about 760nm), and 690nm(from about 670 to about 710nm). These Nd absorption wavelength bands are for the Nd solid state YAG host, and with other solid state hosts for Nd the

wavelengths and widths of these Nd absorption bands may vary. Preferably laser diodes 32 are broad area lasers with each producing about 2 watts of multimode light (2W MM) at 808 nm. With optical element lenses 34 and a polarization combiner 36, the output of broad area laser diodes 32 is inputted into Nd:YAG solid state laser 22.

5 Nd:YAG solid state laser 22 is comprised of a 946 nm laser cavity 38 which includes Nd:YAG crystal 40 and glass substrate spherical surface laser element 42. Nd:YAG crystal 40 includes a 946 nm high reflectivity (about 99%) coating 44 and an anti-reflection coating 48 that prevents reflections (946 nm and 1060 nm) other than at 808 nm, coating 48 may include a 808nm high reflector to provide beneficial reflection of

10 808nm light. Spherical surface laser element 42 includes a coating 50 that provides for high reflectivity (about 95%) at 946 nm and high transmission at 1060 nm. Solid state laser 22 preferably produces at least about 1 watt of single mode light at 946 nm. Preferably light in the range of 780 to 880 nm is inputted into solid state laser 22, most preferably 800 to 880 nm. In addition to this external cavity solid state Nd doped

15 crystal embodiment of solid state laser 22, solid state laser 22 may comprise a tapered Nd doped waveguide laser device or a Nd doped double clad optical waveguide fiber laser device.

As shown in FIG. 1, optical waveguide device 18 includes a lasing waveguide 24 that is comprised of a Yb doped optical waveguide 26. Yb doped optical waveguide

20 26 has an input end 28 and an output end 30. Input end 28 is optically coupled to solid state laser 22 such that the emission  $\lambda_{ss}$  outputted from solid state laser 22 is inputted into the lasing Yb doped optical waveguide and an emission  $\lambda_y$  centered about 980 nm is outputted from lasing waveguide output end 30.

Yb doped optical waveguide 26 is preferably a silica optical waveguide fiber that is doped with Yb. It is further preferred that the silica optical fiber is an aluminosilicate fiber such as a silica optical fiber doped with Al and Yb. In a most preferred embodiment the Yb doped optical waveguide is Er free, in that the waveguide does not contain erbium so that the Yb ions are the excitable ions in the waveguide. Preferably the Er free Yb doped waveguide is a silica waveguide fiber.

30 Preferably the Yb doped silica fiber is comprised of 60 to 99 wt.%  $\text{SiO}_2$ . Preferably Yb doped waveguide 26 is a silica fiber which includes 0.1 to 4 wt.% Yb and 0.1 to 10 wt.% Al, and most preferably a waveguide with 0.2 to 2.5 wt.% Yb and

0.2 to 9wt.% Al, with a further preferred Al wt.% of 0.2 to 8.3wt.% Al.. In a preferred embodiment the Yb doped silica fiber composition further comprises Ge (germanium).

It is preferred that lasing waveguide 24 and Yb doped optical waveguide 26 are comprised of single mode optical waveguide fiber with such single mode optical  
5 waveguide fiber the guiding of light by the waveguide is restrained to a single mode. Additionally, Yb doped optical waveguide 26 is preferably a single cladding optical fiber, in that the optical fiber has a single clad as compared to a double clad optical fiber or other multi-clad fibers. Preferably Yb doped waveguide 26 consists essentially of a single waveguide cladding and a waveguiding core so that the optical waveguide  
10 fiber only has a single waveguide cladding surrounding a waveguide core with appropriate optical fiber protective coatings.

As shown in FIG. 1, optical waveguide device 18 includes a filter 52. Filter 52 is a filter for inhibiting light having a wavelength  $\lambda_x$  centered about 1030 nm from propagating in Yb doped optical waveguide 26. Light removal filter 52 removes  
15 nm light so that light produced in the Yb doped waveguide 26 is biased towards the production of 980 nm light. Preferably filter 52 is positioned outside of the 980 nm resonant cavity and most preferably is a fiber grating positioned between solid state laser 22 and Yb doped optical waveguide input end 28. As depicted in FIG. 1, fiber filter 52 is preferably a long period fiber grating that removes unwanted 1030 nm light  
20 that may be produced by solid state laser 22. Filter 52 removes and prevents detrimental light having a wavelength centered about 1030 nm from degrading the performance of lasing waveguide 24 and ensures that the beneficial 946 nm excitation light is utilized by Yb ions to produce 980 nm light and to suppress the production of 1030 nm light by Yb ions in Yb doped waveguide 26. In addition to a long period  
25 grating, filter 52 can comprise a filter such as a dielectric thin film filter which also removes the unwanted 1030 nm light that is produced by excited Yb ions.

As shown in FIG. 1, lasing waveguide 24 preferably includes at least one fiber Bragg grating. Fiber Bragg gratings provide a beneficial means of reflecting light in an optical fiber waveguide format. Lasing waveguide 24 includes a back reflector 54  
30 proximate Yb doped optical waveguide input end 28. Back reflector 54 is centered about 980 nm and is highly reflective so as to benefit the output of 980 nm light from the lasing waveguide. Lasing waveguide 24 includes a pump reflector 56 proximate Yb

doped optical waveguide output end 30. Pump reflector 56 is centered about 946 nm and is highly reflective so that 946 nm pump light that reaches the end of the Yb doped waveguide is contained in the Yb doped waveguide so that it can pump Yb ions into the proper excited state. Lasing waveguide 24 includes an output coupler 58 proximate Yb doped optical waveguide output end 30. Output coupler 58 is centered about 980 nm and is less reflective than back reflector 54 so as to benefit the output of 980 nm light from the lasing waveguide. Output coupler 58 and back reflector 54 are fiber Bragg gratings that provide reflectivity of light to benefit the lasing operation. Pump reflector 56 is also a fiber Bragg grating that provides beneficial reflections. These fiber Bragg gratings can be made in separate optical waveguide fibers which are spliced together with Yb doped optical waveguide fiber 26 to form lasing waveguide 24 or could be one unitary, integral, and complete single optical fiber or spliced variations thereof.

Yb doped optical waveguide 26 has a gain  $G_{980}$  at 980 nm and a gain  $G_{1030}$  at 1030 nm with  $G_{980} > G_{1030}$ . Output coupler 58 of lasing waveguide 24 has a reflectivity OCR, and Yb doped waveguide 26 has a Yb weight percent concentration  $CONC_{Yb}$ , a pump absorption  $PA_{946}$  at 946nm (percent of 946nm pump power absorbed by the Yb ions) which depends on the 946 nm pump power and the removal of 1030 nm light by 1030 nm light removal filter 52, and a length  $L_{Yb}$ , wherein gain  $G_{980}$  is dependent on  $CONC_{Yb}$ ,  $PA_{946}$  and OCR and the waveguide length  $L_{Yb}$  is optimized such that  $G_{980} > G_{1030}$  with  $G_{980}$  depending on  $CONC_{Yb}$ , OCR,  $PA_{946}$  and  $L_{Yb}$ . For a given  $CONC_{Yb}$ ,  $PA_{946}$  and OCR, the length  $L_{Yb}$  is set at an optical length so that  $G_{980} > G_{1030}$  and beneficial production of 980 nm light is obtained. In practicing the invention it has been found that for a  $CONC_{Yb}$  of about 0.2 wt.% Yb, a  $PA_{946}$  greater than 90% (with the long period fiber grating filter removing 1030 nm light), and an OCR reflectivity of about 5% at 980 nm, that the optimized optical fiber length is at about 60 cm. For a given inputted pump power the length is adjusted to insure  $G_{980} > G_{1030}$ . If light removal long period fiber grating filter 52 is not utilized to remove 1030 nm light and bias the production of 980 nm light by 946 nm pump light, then  $PA_{946}$  needs to be kept below 60% so that  $G_{980} > G_{1030}$  and to maintain the production of 980 nm which results in wasting 946 nm pump power.

Optical waveguide device 18 of the invention provides at least 300 milliwatts (mW) of 980 nm output which is readily usable for pumping an optical amplifier and

meets the high pump power demands of optical amplifiers. Preferably lasing waveguide 24 produces a 980 nm single mode output of at least .5W (a half of a watt). Yd doped optical waveguide output end 30 is optically coupled to an Er doped optical amplifier 60 as depicted in FIG. 1. As such, the invention comprises an optical amplifier pump that produces at least 500 milliwatts of 980 nm pump power and includes a semiconductor laser. Preferably the waveguide device of the invention has a Yb laser slope efficiency of at least 80%. With such, the inventive device provides an optical to optical conversion efficiency greater than 25% (1 W out at 980nm, 4W in at 808nm), preferably greater than 30%, more preferably greater than 40%, and most preferably greater than 50%.

The invention further includes a method of producing a 980 nm pump light. This method of producing a 980 nm pump light includes the steps of providing a first laser for producing an emission  $\lambda_1$  centered about 808 nm; inputting the emission  $\lambda_1$  into a second laser for producing an emission  $\lambda_2$  centered about 946 nm; producing emission  $\lambda_2$ , centered about 946 nm; inputting the produced emission  $\lambda_2$  into a third laser for producing an emission  $\lambda_3$  centered about 980 nm; and then producing emission  $\lambda_3$  centered about 980 nm.

The step of providing a first laser for producing  $\lambda_1$  and inputting  $\lambda_1$  includes providing a semiconductor laser 32 and coupling semiconductor laser 32 into solid state laser 22. The method preferably includes providing a second semiconductor laser 32 for producing the emission  $\lambda_1$  centered about 808 nm, and polarization multiplexing or wavelength multiplexing the first laser 32 and the second semiconductor laser 32. Preferably first laser 32 and second semiconductor laser 32 are broad-area laser diodes which produce a multimode emission  $\lambda_1$ .

Preferably the second laser which provides emission  $\lambda_2$  centered about 946 nm is a solid state laser 22, most preferably a Nd doped laser, such as a Nd:YAG laser which comprises a Yd doped solid state lasing waveguide laser, such as a Yb doped laser fiber 26.

Preferably the method of producing a 980 nm pump light includes the step of inhibiting the feedback of 1030 nm light into third laser 24, such as by filtering with filter 52. As shown in FIG. 1, the method further includes inputting the produced emission  $\lambda_3$  centered about 980 nm into Er doped optical amplifier 60.



In a further aspect the invention includes an optical amplifier device 18 which includes a semiconductor 32 which produces an emission  $\lambda_1$  centered about a first semiconductor wavelength and a first solid state laser 22 which is optically pumped by semiconductor laser 32. First solid state laser 22 produces an emission  $\lambda_2$  centered  
5 about a first solid state wavelength in the Yb absorption spectrum peak that is centered about 920 nm. The device further includes a second solid state laser 24 that is optically pumped by first solid state laser 22. Second solid state laser 24 produces an emission  $\lambda_3$  centered about 980 nm and optical amplifier 60 for amplifying an optical transmission signal is optically pumped by second solid state laser 24. Preferably the  
10 first solid state laser 22 is a Nd doped laser and the first solid state wavelength is in the range of 880 to 960 nm. Preferably second solid state laser 24 is comprised of an optical waveguide which includes a Yb doped silica optical waveguide fiber 26. Additionally, second solid state laser 24 preferably includes a fiber Bragg grating back reflector 54 and a fiber Bragg grating pump reflector 56. In a most preferred  
15 embodiment of the invention the device includes filter 52 for inhibiting light having a wavelength proximate 1030 nm from entering second solid state laser 24.

The invention further includes a method of amplifying an optical transmission signal, which includes: providing a third laser for producing  $\lambda_3$  light; providing an optical amplifier which utilizes  $\lambda_3$  light to amplify an optical signal; pumping the  
20 second laser with  $\lambda_1$  light produced by the first laser, pumping the third laser with  $\lambda_2$  light produced by the second laser, and pumping the optical amplifier with the  $\lambda_3$  light. Preferably with the method  $\lambda_3 > \lambda_2 > \lambda_1$ , and most preferably the method includes amplifying an optical transmission signal which has a wavelength  $\lambda_4$  such that  $\lambda_4 > \lambda_3 > \lambda_2 > \lambda_1$ . In preferred methods:  $\lambda_1$  light is centered about 808 nm;  $\lambda_2$  light is centered  
25 about 946 nm; and  $\lambda_3$  light is centered about 980 nm. The method also further includes suppressing light having a wavelength centered about 1030 nm, such as with a filter 52.

The invention further comprises a method of making a 980 nm pump for an optical amplifier which includes the steps of providing at least one semiconductor laser diode, coupling at least one semiconductor laser diode into a solid state laser, and  
30 coupling the solid state laser into a Yb doped optical fiber laser. Preferably the step of providing at least one semiconductor laser diode 32 comprises providing at least two semiconductor laser diodes 32, most preferably providing two broad area

semiconductor lasers with each of the semiconductor lasers outputting at least 2W (two watts) each at a wavelength centered about 808 nm and coupling into a solid state laser includes combining the polarization of the two semiconductor lasers. Preferably the solid state laser 22 comprises a Nd doped solid state laser. Preferably Yb doped optical waveguide fiber laser 24 comprises a single clad single mode alumino-silicate Yb doped fiber 26.

In an additional aspect, the invention includes an optical amplifier system that comprises a single cladding optical waveguide lasing fiber and a multimode pump source. As shown in FIG. 1, the optical amplifier system of the invention comprises single cladding optical waveguide lasing fiber 126 and multimode pump source 132. Preferably single cladding optical waveguide lasing fiber 126 comprises a single mode Yb doped optical 26 and multimode pump source 132 is comprised of a first and second broad area semiconductor laser 32. Most preferably the single cladding optical waveguide lasing fiber is indirectly pumped by said multimode pump source.

Additionally, the invention includes a method of making an optical amplifier pump which comprises providing a multimode pump source 132, providing a single cladding optical waveguide lasing fiber 126 and indirectly pumping the lasing fiber 126 with multimode pump source 132.

In a further aspect the invention comprises a method of amplifying an optical signal  $\lambda_i$  by providing a multimode light pump source having a wavelength  $\lambda_{mm}$  multimode brightness output; converting the multimode brightness output into a single mode output having a wavelength  $\lambda_{pump}$ ; and inputting the single mode output into an optical amplifier for amplifying an optical signal  $\lambda_i$ . Preferably  $\lambda_i > \lambda_{pump} > \lambda_{mm}$ .

Additionally, the invention includes an optical amplifier pump for pumping an optical amplifier with a pump wavelength  $\lambda_{pump}$ , with the pump including a semiconductor laser which produces a wavelength  $\lambda_{semi}$  and the pump outputting at least 500mW of light at  $\lambda_{pump}$ . Preferably  $\lambda_{semi}$  is not equal to  $\lambda_{pump}$  ( $\lambda_{semi} \neq \lambda_{pump}$ ) and most preferably  $\lambda_{semi}$  is less than  $\lambda_{pump}$  ( $\lambda_{semi} > \lambda_{pump}$ ). Preferably  $\lambda_{semi}$  is in the range of 780 to 880 nm, and most preferably  $\lambda_{semi}$  is at a wavelength which excites neodymium ions. In a preferred embodiment  $\lambda_{pump}$  is centered about 946 nm. In a further preferred embodiment  $\lambda_{pump}$  is centered about 980 nm.

In a further aspect the invention includes an optical amplifier pump with a semiconductor laser which produces a wavelength  $\lambda_1$  for pumping Nd ions, a plurality of Nd ions which when pumped by the wavelength  $\lambda_1$  produces a wavelength  $\lambda_2$  for pumping Yb ions, and a plurality of Yb ions which when pumped by the wavelength  $\lambda_2$  produces a wavelength  $\lambda_3$  for pumping Er ions. Preferably  $\lambda_1$  is in the range of 780 to 880 nm,  $\lambda_2$  is in the range of 900-960 nm, and  $\lambda_3$  is in the range of 970-980 nm.

In addition, the invention includes an optical amplifier pump for pumping an optical amplifier which amplifies optical signals in the L-band range of 1560 to 1620 nm which comprises at least one broad area semiconductor laser and a neodymium doped solid state laser with the neodymium doped solid state laser pumped by the semiconductor laser. As shown in FIG. 3, optical amplifier pump 120 comprises using the first part 110 of laser system 20 of FIG. 1 to directly pump L-band optical amplifier 160 with the 946 nm output from Nd doped solid state laser 22. Broad area semiconductor lasers 32 pump solid state laser 22 which inputs the 946 nm light directly into L-Band optical amplifier 160 without utilizing the Yb doped optical fiber. Pump 120 effectively pumps an L-band optical amplifier such as a long length of Er doped Al doped silica amplifier fiber.

The application of the invention to directly pump a L-band optical amplifier includes an optical amplifier 160 which has a semiconductor 32, a solid state laser 22 which is pumped by semiconductor laser 32, and an Er doped optical amplifier fiber 260 for amplifying signals in the range of 1560 to 1620 nm with the amplifier fiber pumped by solid state laser 22. Preferably Er doped optical amplifier fiber 260 is a long length of fiber having a length in the range of 50 to 250 meters, and more preferably 100 to 200 meters. Preferably solid state laser 22 is comprised of neodymium, such as a neodymium doped solid state laser. Preferably semiconductor lasers 32 are broad area multimode semiconductor lasers. The neodymium doped solid state laser may comprise a Nd doped crystal, a Nd doped double clad waveguide, or a Nd doped tapered waveguide. A Nd doped crystal is the preferred solid state laser, with Nd:YAG most preferred.

The invention includes a method of amplifying a L-band optical signal which includes the steps of providing an Er doped optical fiber, pumping a neodymium solid state laser with a broad area semiconductor laser, inputting the solid state laser directly

into the Er doped optical fiber, and amplifying a L-band optical signal with the Er doped optical fiber. In a preferred method the provided Er doped fiber has a length of at least 100 meters, and most preferably has a length from 100 to 200 meters. Most preferably the Er doped optical fiber is an Al doped silica fiber.

5

### Examples

The invention will be further clarified by the following examples which are intended to be exemplary of the invention.

#### 10 Example 1-2

As shown in FIG.1-2, a single-mode Yb:SiO<sub>2</sub> fiber laser pumped by a diode-pumped 1.1 W Nd:YAG laser at 946 nm in accordance with the invention provided >650 mW output power at 980 nm and >80% slope efficiency. Such high output power at 980 nm was achieved by pumping at 946 nm using a TEM<sub>0,0</sub> laser-diode-pumped Nd:YAG. Although the Yb absorption cross section has a minimum near this wavelength, there was still enough absorption to provide the 980nm output. This inventive pumping scheme obtained 0.65 W of single-mode output from a CS980 brand optical fiber (Corning Incorporated; Corning, NY) output fiber, and is scaleable to much higher output powers and has been found to be useful for pumping Er-doped amplifiers. In this high output power operation of the invention the 1030 nm transition was suppressed.

In practicing the invention as shown in FIG. 1 and described herein, the invention involves the quasi-four-level transition of Nd:YAG at 946 nm to directly pump Yb:SiO<sub>2</sub> which lases at 980 nm and directly pumps Er. Such production of 980 nm pump light has provided certain advantages such as compatibility with existing amplifier component technology and pre-amp stage pumping without significant NF degradation as observed with Yb:Er co-doped fibers.

As shown in FIG 1-2, the TEM<sub>0,0</sub> pump laser consisted of a Nd:YAG solid state crystal pumped by a pair of polarization-multiplexed 2W multimode, broadened-waveguide, broad-area semiconductor laser diodes at 808 nm with emitting aperture of 100 X 1 μm<sup>2</sup>. The solid state laser crystal had a 1 dB absorption length of 3 mm, and dimensions 3X3X8 mm. The plano-concave resonator had a length of 7 mm (optical

30

length is 1cm). The radius of curvature was about 10 cm and the thermal lens at 4 W pump power was about 15 cm. Thermal lensing caused the resonator spot size to decrease with increasing pump power, and therefore beam divergence increased with pump power. This was verified experimentally, with measured TEM<sub>0,0</sub> beam  
5 divergence in the range 3.4-6 mrad, depending on output power. A schematic of the Nd:YAG laser is shown in FIG. 2. The threshold and slope efficiency of this laser was 1 W of input pump power and 50%, respectively. It had a FWHM of 0.30 nm centered at 945.8 nm. The Nd:YAG solid state crystal laser utilized in the invention was obtained from InnoLight GmbH (Hannover, Germany) and the broad-area  
10 semiconductor laser diodes were Polaroid POL-5100BW series brand laser diodes (Polaroid Corporation; Norwood, MA). The laser diodes were collimated in the fast axis by a  $\mu$ -lens element with 100  $\mu$ m diameter. This reduced the fast axis NA from 0.6 to about 0.03. An image of the  $\mu$ -lens aperture was made by a spherical lens element which had a focal length of 1.8 cm. The beams from each laser diode were spatially  
15 overlapped in the polarization multiplexer and magnified X 1.5 by a lens element, which had a focal length of 2.7 cm. The focused pump spot radius ( $1/e^2$ ) was approximately  $80 \pm 10$   $\mu$ m. The measured laser beam spot radius at 100 mW output power was 80-100  $\mu$ m, corroborating good pump-signal overlap necessary for efficient quasi-four-level operation.

20 With a double-pass pump absorption using appropriate coatings in the Nd:YAG laser resonator, about 1.7 W at 946 nm can be achieved with the same 2X2W laser diode pumps. With 85% coupling of this 1.7 W output into the fiber and an 80% Yb laser slope efficiency, greater than 1.2 W @ 980 nm should be obtained.

The Yb doped fiber laser consisted of a length of Yb-doped fiber with 2 gratings  
25 fusion spliced on each side of it as illustrated in FIG. 1. In the input side, pump power was coupled through a X10 aspheric lens element (Newfocus brand lens #5726) into Flexcore 1060 brand optical fiber (Corning Incorporated; Corning, NY) containing a 1030nm long-period grating (LPG) which was spliced to CS980 brand optical fiber (Corning Incorporated; Corning, NY) containing a Bragg grating back reflector. In the  
30 output side, Flexcore 1060 brand optical fiber (Corning Incorporated) containing a Bragg grating pump reflector was spliced to CS980 brand optical fiber (Corning Incorporated) containing a Bragg grating output coupler.

It was found that efficient pump absorption and exclusive three-level laser operation pull the required Yb fiber length in opposite directions; it was found that 946 nm pump absorption should be at most 4-5 dB at threshold, in order to avoid quasi-four-level oscillation in a fiber laser with 14 dB round-trip loss. Since low pump absorption was unacceptable, a spectral filter was used to increase pump absorption. The Yb-doped alumino-silicate fiber with length of 50 cm allowed  $\approx 85\%$  absorption of pump power just below laser threshold; however, besides three-level oscillation between the  $^2F_{5/2} \rightarrow ^2F_{7/2}$  manifolds at 978 nm, unwanted quasi-four-level lasing at 1030 nm and at 1012 nm between two other pairs of strong Stark levels of the same manifolds was simultaneously observed. This was eliminated by the LPG which had a 13 dB notch at 1027 nm; this grating had a loss of 0.15 dB at 946 nm and 1.2 dB at 1012 nm.

The back reflector was a 0.5 nm FWHM FBG centered at 979.8 nm with peak reflectivity  $>99\%$ . The pump reflector was a 0.6 nm FWHM FBG centered at 945.8 nm with peak reflectivity of  $>99\%$ ; this grating allowed  $\approx 97\%$  pump absorption in a double-pass; for the given fiber length, by taking the pump reflector out about 15% of pump power leaks from the fiber end; it was found that the pump reflector grating also helped to suppress unwanted oscillation at 1012 nm. The output coupler had a 0.5 nm FWHM centered at 979.9 nm with peak reflectivity of 5%; this grating maintained narrow-line oscillation at high pump powers. Without the output coupler, the fiber lased between its cleaved facets at high pump power. The Yb: SiO<sub>2</sub> fiber was 0.2 wt.% Yb and 0.2 wt. Al, NA=0.22, cut-off wavelength of 870 nm and peak absorption of 1.77 dB/cm at 980 nm with background loss of 8 dB/km.

The laser power measured from a cleaved facet of the output CS980 fiber end is shown in FIG. 4 vs. input pump power (measured before the Newfocus brand x10 aspheric lens element); black dots 401 represent result points and solid line 402 is a linear interpolation of these results. Threshold was approximately 41 mW of input pump power and the slope efficiency was 59 % with respect to input pump power. Measured losses were as follows: 1.0 dB fiber coupling loss (which corresponds to a coupling efficiency of 88% taking into account the lens 97% transmission and 7% Fresnel reflection from fiber facets), 0.25 dB splicing loss (for a total of 4 splices) and 0.15 dB LPG insertion loss, for a total of about 1.4 dB. After correcting for these

losses, the laser slope efficiency is 81% and laser threshold is 30 mW, both with respect to absorbed pump power. The spectrum at 655 mW output power is shown in FIG. 5; it has a FWHM of 0.15 nm centered at 979.8 nm.

A second alumino-silicate Yb-doped fiber was utilized in the invention, having 2.5 wt.% Yb and 8.3 wt.% Al, NA=0.26, cut-off wavelength of 940 nm and peak absorption of 9.75 dB/cm at 980 nm with background loss of 20 dB/km. A 9.5 cm length of this Yb-doped fiber allowed about 85% pump absorption, with measured threshold and slope efficiency of approximately 60 mW and 60%, with respect to absorbed pump power.

These alumino-silicate Yb-doped fibers were prepared by the method by MCVD (modified chemical vapor deposition) process. The results for measured slope efficiency and power threshold are summarized in Table 1. In each case, the Yb fiber length was optimized for lasing at 980 nm with 90% pump absorption, and splice losses were reduced to a minimum. These measurements were obtained with input LPG and back reflector in place, but no gratings in the output end in that the output reflector was the cleaved Yb fiber facet

TABLE 1.

Fiber	Composition (oxide wt.%)	Length for 90% pump absorp- tion (cm)	Pump power threshold (mW)	Slope efficienc y
Reference	0.06Yb	50	12	0.67
First Example	0.2Yb/0.2Al	60	28	0.79
Second Example	2.5Yb/8.3Al/0.5Ge	10	56	0.57

All of these fiber lasers contained two splices: one Flexcore to CS980 splice which consistently had a measured loss of  $<0.1$  dB, and one CS980 to Yb fiber with estimated loss  $<0.2$ . The numbers for slope efficiency and threshold were obtained by linear fit to measured input/output points and corrected for pump leakage, pump coupling and  
5 Flexcore-CS980 splice loss; they were not corrected for the less reproducible CS980-Yb fiber splice loss; thus, slope efficiency with respect to absorbed pump power may be up to 5% higher in these alumino-silicates.

FIG. 6 shows typical spectra observed without the output gratings (pump reflector and output coupler) for 300 mW of output power. Curve 601 shows how the  
10 spectrum breaks with only the LPG and back reflector FBG in place; about 92% of the laser power output is within the FBG bandwidth; weak spurious feedback causes the remaining 8% to be emitted near the peak of the  $^2F_{5/2} \rightarrow ^2F_{7/2}$  transition at 978 nm. For comparison, the free-running spectrum (curve 602) and the spectrum obtained with the FBG replaced by a chirped FBG (curve 603) are also shown; the former has a  
15 FWHM of 3.3 nm centered at 978.0 nm, while the latter has a FWHM of 3.2 nm centered at 979.0 nm. The chirped FBG had reflectivity  $> 98\%$  over 25 nm centered at 980.0 nm. Thus the use of proper gratings provided bandwidth control.

### Example 3

20 The Nd doped solid state laser system was utilized to directly pump an Er doped L-Band optical amplifier to provide optical amplification in the 1560 to 1620 range. As shown in FIG.3, the Nd:YAG solid state laser output of about 1 watt at 946nm was directly coupled into a L-Band optical amplifier so that approximately 29 dBm of 946 nm light was inputted into a 200 meter length of Er doped optical amplifier fiber. The  
25 Er doped optical amplifier fiber was a silica fiber doped with Er and Al. This provided about 22dBm of amplified output power at 1585 nm with 8.9dBm of input power at 1585 nm. Er propagation loss of about 20dBm/km were estimated and the Er absorption at 940 nm was measured to be about 0.2dB/m.

It will be apparent to those skilled in the art that various modifications and  
30 variations can be made to the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the



modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. An optical waveguide device comprised of:

a solid state laser for outputting an emission  $\lambda_{ss}$  centered about 946 nm, a lasing waveguide, said lasing waveguide comprising a Yb doped optical waveguide, said Yb doped optical waveguide having an input end and an output end, said input end is optically coupled to said solid state laser such that said emission  $\lambda_{ss}$  outputted from said solid state laser is inputted into said Yb doped optical waveguide input end and an emission  $\lambda_y$  centered about 980 nm is outputted from said Yb doped optical waveguide output end.

2. A method of producing a 980 nm pump light, said method comprising:

providing a first laser for producing an emission  $\lambda_1$ , centered about 808 nm;

inputting said produced emission  $\lambda_1$ , centered about 808 nm into a second laser for producing an emission  $\lambda_2$  centered about 946 nm;

producing an emission  $\lambda_2$  centered about 946 nm;

inputting said produced emission  $\lambda_2$  centered about 946 nm into a third laser for producing an emission  $\lambda_3$  centered about 980 nm;

producing an emission  $\lambda_3$  centered about 980 nm.

3. An optical amplifier device comprised of:

a semiconductor laser which produces an emission  $\lambda_1$ , centered about a first semiconductor wavelength;

a first solid state laser which is optically pumped by said semiconductor laser, said first solid state laser produces an emission  $\lambda_2$  centered about a first solid state wavelength, said first solid state wavelength in the Yb absorption spectrum peak centered about 920 nm;

a second solid state laser which is optically pumped by said first solid state laser, said second solid state laser produces an emission  $\lambda_3$  centered about 980 nm;

an optical amplifier for amplifying an optical transmission signal, said optical amplifier optically pumped by said second solid state laser.

4. A method of amplifying an optical transmission signal, said method comprising:

providing a first laser for producing  $\lambda_1$  light;

providing a second laser for producing  $\lambda_2$  light;

5 providing a third laser for producing  $\lambda_3$  light;

providing an optical amplifier which utilizes  $\lambda_3$  light to amplify an optical signal;

pumping said second laser with  $\lambda_1$  light produced by said first laser;

pumping said third laser with  $\lambda_2$  light produced by said second laser; and

10 pumping said optical amplifier with  $\lambda_3$  light.

5. A method of making a 980 nm pump for an optical amplifier comprising:

providing at least one semiconductor laser diode;

coupling said semiconductor laser diode into a solid state laser;

15 coupling said solid state laser into a Yb doped optical fiber laser.

6. A method of making an optical amplifier pump, comprising the steps of:

providing a multimode pump source;

providing a single cladding optical waveguide lasing fiber; and

20 indirectly pumping said lasing fiber with said multimode pump source.

7. A method of amplifying an optical signal  $\lambda_s$ , comprising the steps of:

providing a multimode light pump source having a wavelength  $\lambda_{mm}$  multimode brightness output;

25 converting said multimode brightness output into a single mode output having a wavelength  $\lambda_{pump}$ ;

inputting said single mode output into an optical amplifier for amplifying an optical signal  $\lambda_s$ .

30

8. An optical amplifier pump for pumping an optical amplifier with a pump wavelength  $\lambda_{\text{pump}}$ ,

said pump including a semiconductor laser which produces a wavelength  $\lambda_{\text{semi}}$ ;

5                      said pump outputting at least 500 mW of light at  $\lambda_{\text{pump}}$ .

9. An optical amplifier pump comprising:

a semiconductor laser which produces a wavelength  $\lambda_1$  for pumping Nd ions;

10                    a plurality of Nd ions, which when pumped by said wavelength  $\lambda_1$ , produces a wavelength  $\lambda_2$  for pumping Yb ions;

a plurality of Yb ions, which when pumped by said wavelength  $\lambda_2$  produces a wavelength  $\lambda_3$  for pumping Er ions.

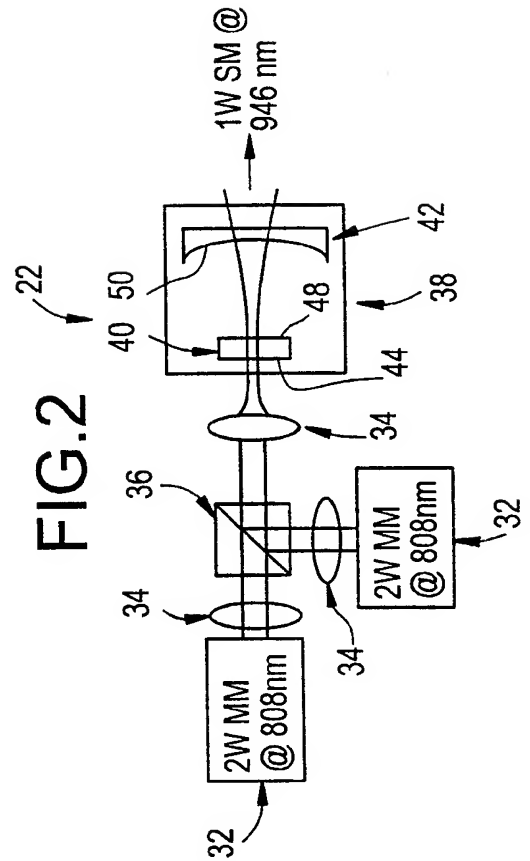
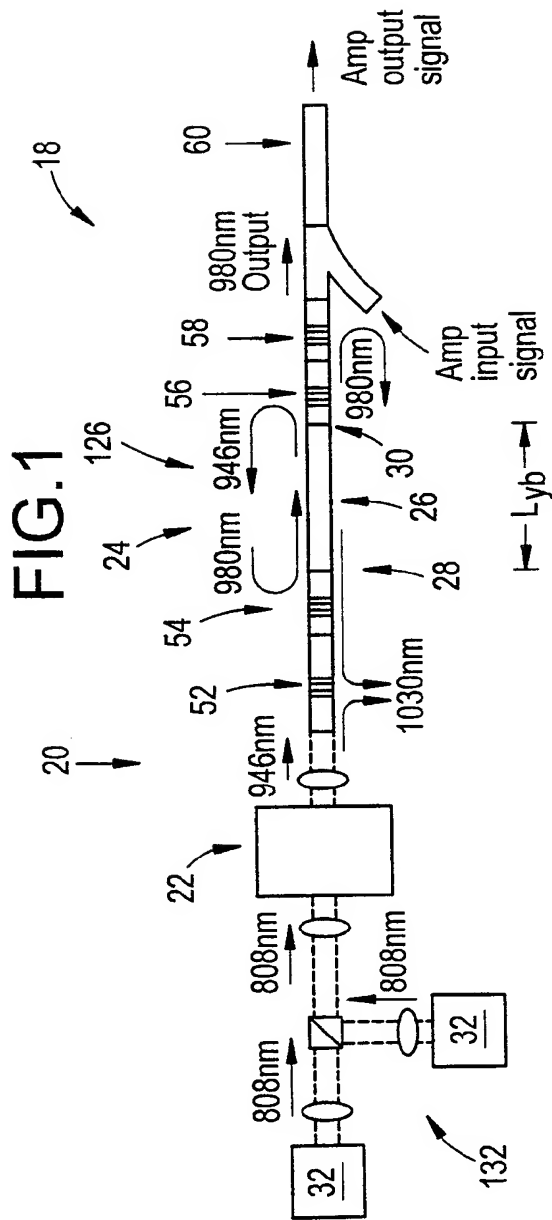
15                    10. A method of amplifying a L-band optical signal comprising:

providing an Er doped optical fiber;

pumping a neodymium solid state laser with a broad area semiconductor laser;

inputting said solid state laser into said Er doped optical fiber; and

20                    amplifying a L-band optical signal with said Er doped optical fiber.



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FIG.3

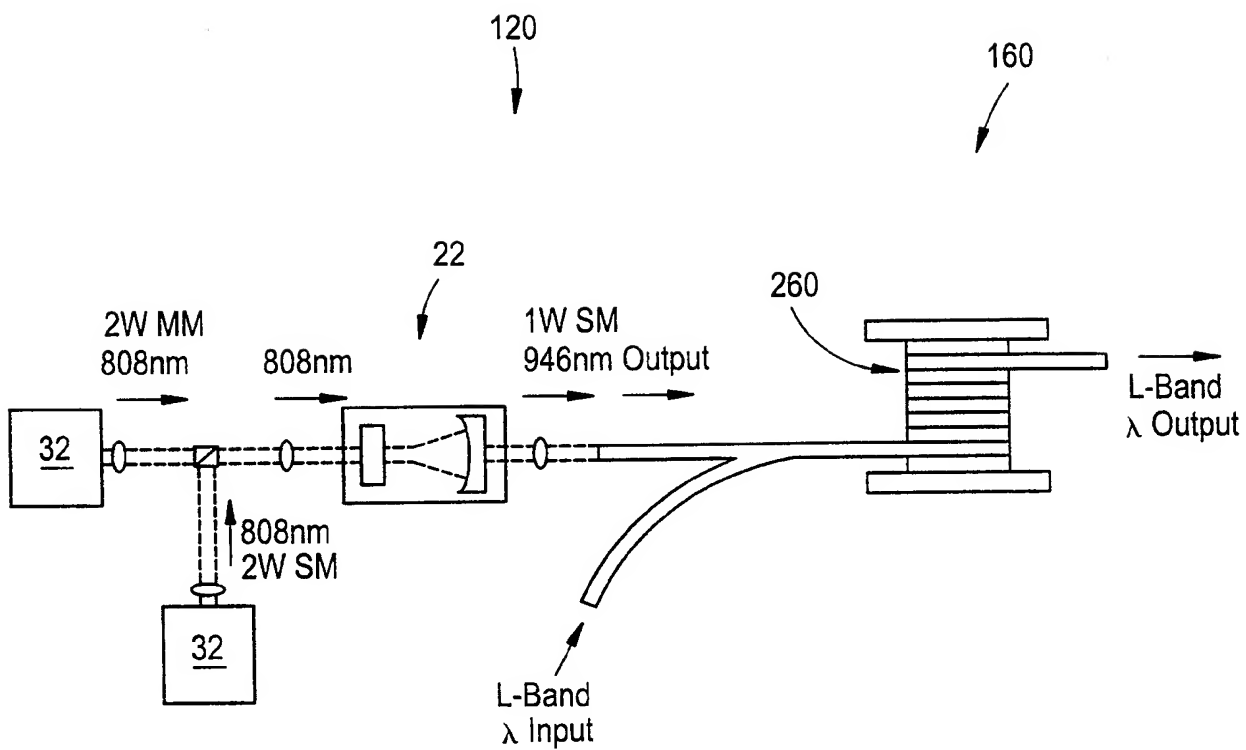


FIG.4

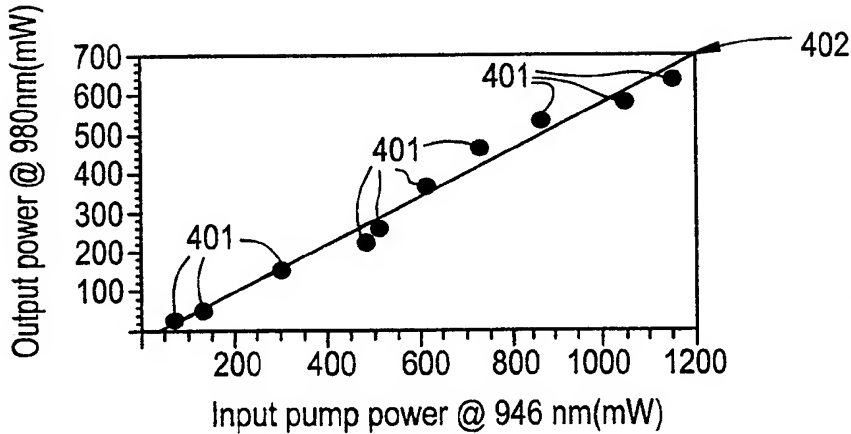


FIG.5

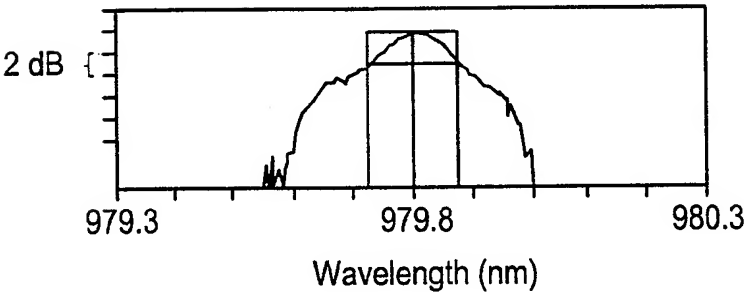
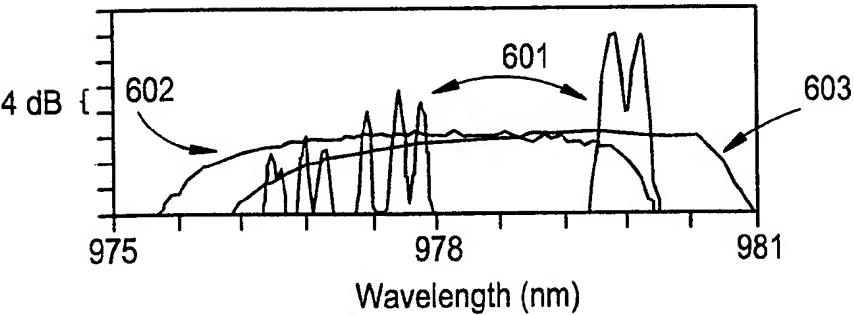


FIG.6



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/29629

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7 H01S3/067 H01S3/094 H01S3/16

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	column 1, line 54 -column 1, line 62 column 2, line 11 -column 2, line 33 column 3, line 19 -column 6, line 55 column 7, line 13 -column 7, line 47; figures 1-5 ---	3
X	WO 95 10869 A (ITALTEL SPA ;IRE POLUS CO (RU); SAMARTSEV IGOR (RU); GAPONTSEV VAL) 20 April 1995 (1995-04-20) page 4, line 30 -page 5, line 24 ---	3
X	EP 0 802 592 A (HUGHES AIRCRAFT CO) 22 October 1997 (1997-10-22) column 4, line 5 -column 4, line 55 column 6, line 9 -column 6, line 20; claim 4; figures 1-4 --- -/-	7



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

**\* Special categories of cited documents :****"A"** document defining the general state of the art which is not considered to be of particular relevance**"E"** earlier document but published on or after the international filing date**"L"** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)**"O"** document referring to an oral disclosure, use, exhibition or other means**"P"** document published prior to the international filing date but later than the priority date claimed**"T"** later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention**"X"** document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone**"Y"** document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.**"&"** document member of the same patent family

Date of the actual completion of the international search

18 April 2000

Date of mailing of the international search report

16/05/2000

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/29629

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	WO 97 26688 A (SDL INC) 24 July 1997 (1997-07-24) page 30, line 17 -page 32, line 13; figure 8 ----	3
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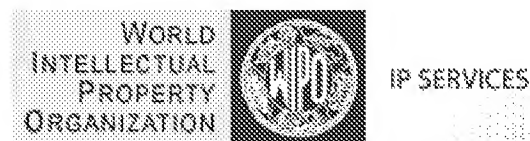
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Information on patent family members

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Search result: 1 of 1

## (WO/2000/043070) THE OPTICAL QUANTUM MEDICAL TECHNOLOGY AND THE INSTRUMENT THEREOF

Biblio. Data Description Claims National Phase Notices Documents

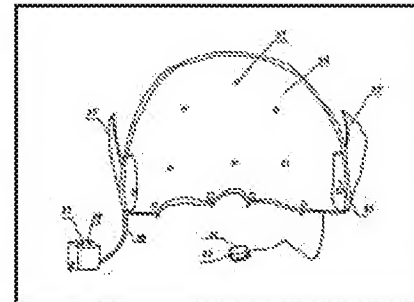
Latest bibliographic data on file with the International Bureau



Pub. No.: WO/2000/043070 International Application No.: PCT/CN2000/000014  
 Publication Date: 27.07.2000 International Filing Date: 24.01.2000  
 Chapter 2 Demand Filed: 21.08.2000  
 IPC: A61N 5/06 (2006.01)  
 Applicant: ZHU, JiLin [CN/CN]; (CN).  
 Inventor: ZHU, JiLin; (CN).  
 Agent: SHENYANG PATENT AGENCY; 60A, No. 66 Xishuncheng Street, Shenhe District, Shenyang 110013 (CN).  
 Priority Data: 99 2 00866.2 25.01.1999 CN  
 99 2 00867.0 25.01.1999 CN

Title: THE OPTICAL QUANTUM MEDICAL TECHNOLOGY AND THE INSTRUMENT THEREOF

**Abstract:** Optical-quantum medical technology and instrument use the incoherent monochromatic source as a new quantum source. The instrument can be practiced in different ways and have got the same effect as that done by laser diode. The invention meets two basic requirements: the monochromaticity of optical; the output power density of optical. Substituting for the helium-neon laser and semiconductor laser used in clinical for several years by latest LED semiconductor light-emitting diode which is newly emerging as optical quantum source, this instrument results in cheaper price, longer period of using, and more convenient maintenance, and can be used in family.



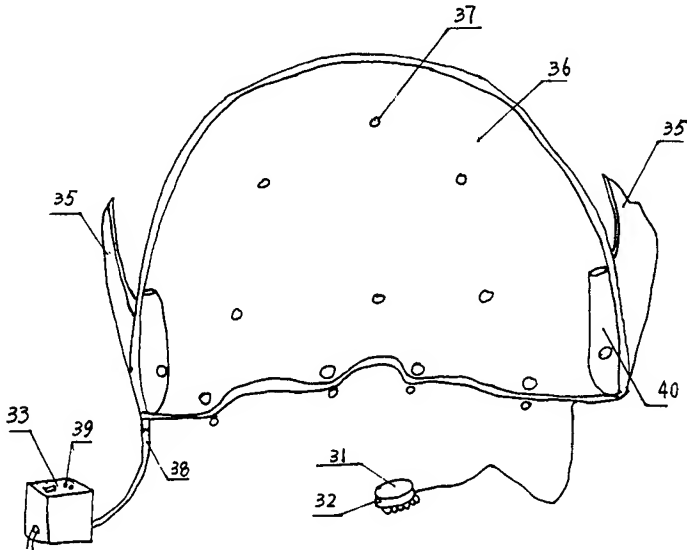
**Designated States:** AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW.  
 African Regional Intellectual Property Org. (ARIPO) (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW)  
 Eurasian Patent Organization (EAPO) (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM)  
 European Patent Office (EPO) (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE)  
 African Intellectual Property Organization (OAPI) (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Publication Language:** Chinese (ZH)

**Filing Language:** Chinese (ZH)



## 按照专利合作条约(PCT)所公布的国际申请

<b>(51) 国际专利分类号<sup>7</sup>:</b> <b>A61N 5/067</b>	<b>A1</b>	<b>(11) 国际公布号:</b> <b>WO00/43070</b> <b>(43) 国际公布日:</b> <b>2000年7月27日(27.07.2000)</b>
<b>(21) 国际申请号:</b> PCT/CN00/00014 <b>(22) 国际申请日:</b> 2000年1月24日(24.01.2000) <b>(30) 优先权:</b> 99200866.2 1999年1月25日(25.01.1999) CN 99200867.0 1999年1月25日(25.01.1999) CN <b>(71)(72) 发明人/申请人:</b> 朱吉林(ZHU, JiLin) [CN/CN]; 中国辽宁省沈阳市和平区和平北大街94号星光大厦, Liaoning 110001 (CN). <b>(74) 代理人:</b> 沈阳市专利事务所(SHENYANG PATENT AGENCY); 中国辽宁省沈阳市沈河区中街路14号, Liaoning 110011 (CN).		<b>(81) 指定国:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO专利(GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), 欧亚专利(AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), 欧洲专利(AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI专利(BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG)  本国际公布: 包括国际检索报告。
<b>(54) Title: THE OPTICAL QUANTUM MEDICAL TECHNOLOGY AND THE INSTRUMENT THEREOF</b>		
<b>(54) 发明名称:</b> 光量子源医疗技术及其医疗器械		
<b>(57) Abstract</b>		
<p>Optical-quantum medical technology and instrument use the incoherent monochromic source as a new quantum source. The instrument can be practiced in different ways and have got the same effect as that done by laser diode. The invention meets two basic requirements: the monochromaticity of optical; the output power density of optical. Substituting for the helium-neon laser and semiconductor laser used in clinical for several years by latest LED semiconductor light-emitting diode which is newly emerging as optical quantum source, this instrument results in cheaper price, longer period of using, and more convenient maintenance, and can be used in family.</p> 		

## (57) 摘要

本发明公开了一种光量子医疗技术及器械, 采用非相干单色光光源为新量子源并制成各种医疗器械, 治疗过去用激光在临床上获得较好疗效的病症。本发明满足了光疗的二大基本要求, 即光的单色性、光的输出功率密度, 具体采用了近两年新兴的 LED 半导体发光二极管为医疗用光量子源, 取代用于临床多年的氦-氖激光器及半导体激光器, 从而取得价格低廉、寿命长、维修方便的效果, 并可成为家庭化的光疗器械。

## 以下内容仅供参考

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AL 阿尔巴尼亚	DM 多米尼加	KR 韩国	RO 罗马尼亚
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AU 澳大利亚	ES 西班牙	LI 列支敦士登	SE 瑞典
AZ 阿塞拜疆	FI 芬兰	LK 斯里兰卡	SG 新加坡
BA 波斯尼亚-黑塞哥维那	FR 法国	LR 利比里亚	SI 斯洛文尼亚
BB 巴巴多斯	GA 加蓬	LS 莱索托	SK 斯洛伐克
BE 比利时	GB 英国	LT 立陶宛	SL 塞拉利昂
BF 布基纳法索	GD 格拉纳达	LU 卢森堡	SN 塞内加尔
BG 保加利亚	GE 格鲁吉亚	LV 拉托维亚	SZ 斯威士兰
BJ 贝宁	GH 加纳	MA 摩洛哥	TD 乍得
BR 巴西	GM 冈比亚	MC 摩纳哥	TG 多哥
BY 白俄罗斯	GN 几内亚	MD 摩尔多瓦共和国	TJ 塔吉克斯坦
BZ 伯利兹	GR 希腊	MG 马达加斯加	TM 土库曼斯坦
CA 加拿大	GW 几内亚比绍	MK 前南斯拉夫马其顿共和国	TR 土耳其
CF 中非共和国	HR 克罗地亚	ML 马里	TT 特立尼达和多巴哥
CG 刚果	HU 匈牙利	MN 蒙古	TZ 坦桑尼亚
CH 瑞士	ID 印度尼西亚	MR 毛里塔尼亚	UA 乌克兰
CI 科特迪瓦	IE 爱尔兰	MW 马拉维	UG 乌干达
CM 喀麦隆	IL 以色列	MX 墨西哥	US 美国
CN 中国	IN 印度	MZ 莫桑比克	UZ 乌兹别克斯坦
CR 哥斯达黎加	IS 冰岛	NE 尼日尔	VN 越南
CU 古巴	IT 意大利	NL 荷兰	YU 南斯拉夫
CY 塞浦路斯	JP 日本	NO 挪威	ZA 南非
CZ 捷克共和国	KE 肯尼亚	NZ 新西兰	ZW 津巴布韦

## 光量子源医疗技术及其医疗器械

### 发明领域

本发明涉及一种物理医疗技术及其医疗器械,尤其是光量子源医疗技术及其医疗器械。

### 背景技术

目前有许多医学书刊杂志、刊登了有关应用激光量子源的医疗技术及器械,如,徐国祥激光医学 1989,王远清激光穴位照射及其临床应用 1993,邓慧珍激光临床应用 1997 等。寻找廉价长寿命光源取代激光光源一直是激光生物医学领域中十分有意义且具有十分明显的经济效益的研究题目。在医疗临床中常用的几种激光器主要是:

1. He-Ne 激光器: 光功率通常为 1-30mw, 红光波长 630 毫微米;
2. CO<sub>2</sub> 激光器: 光功率通常为 0-30w, 红外波长 10.6 微米;
3. GaAs 半导体激光器: 光功率通常为 0-50mw, 近红外波长 900 毫微米;

4. Ar<sup>+</sup>激光器: 光功率通常为 0-5000mw 兰绿波长 480 毫微米。  
上述激光器均具有良好的方向性,相干性,单色性及高亮度(高光功率密度)四大特性。激光器用于光疗临床至今,尤其是弱激光用于皮肤或穴位照射主要是需求输出的光波长应落入血液吸收峰内----即光的单色性,另外是落入病灶区内的光量子密度要求满足医疗的阈值----即输出光功率密度,而对于光的相干性及方向性并无特别要求,特别是采用新光源在靠近体表使用时,方向性则无关重要。因此所寻找的新光源只要其发出的光量子功率密度能达到治疗的阈值且不超过体表皮皮肤烧灼阈,同时其光源波长落入血吸收峰内的单色性即可。

激光光源单色性特别好,光源主峰呈尖状半宽度特别窄,这在激光的技术中具有独特的使用价值,但在医疗中,对象是生物体,机体组织比如血液、淋巴其吸收峰均有一定宽度,且有几段吸收带,每个吸收带宽可达几百毫微米这就为研制满足这种具有一定带宽的单色普通光源提供了可能性。

激光的相干性是激光光源发出的光量子位相相同,这种空间和时间相干效应在激光全息技术激光精密测量等应用中是不可缺少的特性。而在医疗中,生物体内细胞,血液多是动态,流动的,多以大分

子团吸收外界光量子能量来改变病变引起的不平衡态，而对这些光量子的位相即相干性要求不多，即医疗中要求的是落入病灶区的积分效应，这一点是采用非相干光量子源作为医疗光源，取代相干的激光光源的重要根据之一。近几年 LED 半导体光源随着在光通讯中应用的拓展，不断获得更新，现已研制的非相干单色光源无论是光功率密度还是光的输出单色性方面均能满足取代常用的 He-Ne 激光，Ar<sup>+</sup>激光及半导体激光。

近年，自血光量子疗法临床应用十分活跃，现有技术中，血疗临床可以采用两种方法，一种通过体外光照法增加自体血的携氧能力，临床称为 UBI 血氧疗法，早期主要采用紫外线照射；另一种是激光出现以后，采用体内光照即将 He-Ne 激光导入静脉照射，称 ILLI 自血光量子疗法，此法每次需针刺破静脉血管，将光通过光纤将其导入血液中，当血循环时不断增加其携氧能力，从而达到改善心脑血管缺氧而引发的心脏及脑血氧不足的各种疾病，激光疗法减少了体外照射在血液自身感染的几率，但此法每次需对患者刺破静脉光照，食用十分不便。

## 发明目的

本发明的目的在于采用能够满足光疗的两大要素——光量子单色性，光量子落入病灶区的光功率密度的非相干普通光源，取代相干的激光光疗的方法。

本发明的另一个目的在于采用廉价长寿的非相干普通光制备出出一系列廉价长寿的新型医疗器械，其疗效与激光医疗相近。

本发明的另一个目的在于采用廉价长寿的非相干普通光源构成量子无损血氧疗法、头罩、清脑增记面罩等量子护心带以及量子健肾带。

本发明的另一个目的在于采用廉价长寿的非相干普通光源构成量子鼻炎流感治疗器、量子止咳带。

本发明的另一个目的在于采用廉价长寿的非相干普通光源构成美容类器械如量子育发帽、量子除皱美容罩、丰乳罩。

本发明的另一个目的在于采用廉价长寿的非相干普通光源构成量子消炎贴，包括量子腔内消炎、量子氙带、量子痔带、量子骨科消炎贴等。

本发明的另一个目的在于采用廉价长寿的非相干普通光源构成激光增视保健眼镜。

上述量子无损血氧疗仪、清脑增记面罩、量子护心带、量子健肾带、量子鼻炎流感治疗器、量子止咳带、量子育发帽、量子除皱美容罩、丰乳罩、量子消炎贴、激光增视保健眼镜等预料器械，能满足光疗的两大要素——光量子单色性，光量子落入病灶区的光功率密度，并可取代相干的同类激光医疗器械，其疗效与激光疗效相同。

### 简要说明

本发明的目的可以通过以下的技术方案来实现：一种光量子源医疗技术，其特征在于：用非相干单色光源且能达到医疗所需的光功率密度，用以取代相干的激光光源的光疗技术的方法。

本发明中选取以下非相干单色光量子光源为光源：

1) 近红外光量子源：950/近红外发光材料：CaAs 半导体 LED 发光二极管，其主峰 950 毫微米，单支发光管发光功率 50-100 毫瓦，可取代半导体激光器为新型非相干近红外医疗用单色光源；

2) 红光量子源：660/红色发光材料：CaAlAs 半导体 LED 发光二极管，其主峰 660 毫微米，发光管单支光功率 5-10 毫瓦，可取代 He-Ne 激光用于医疗用单色光源；

3) 兰光量子源：450/兰色 发光材料：Al<sub>2</sub>O<sub>3</sub>，LED450/兰色，其发光主峰 450 毫微米，发光管单支功率 5 毫瓦，多支组合可代替 Ar<sup>+</sup> 激光用于医用单色光源。

以上发光管光谱宽度一般为几十毫米，单色性完全可以达到医疗的要求，这种光源用于制成上述各种医疗器械而能推广到家庭使用。

一种光量子源医疗器械，其特征在于：用能达到医疗所需的光功率密度的非相干单色光源作为光量子源，并配以电源和治疗器组成医疗器械，用以取代相干的激光光源及医疗器械。所述的医疗器械包括量子光源、紧固带、穴位光针、量子插座、电源盒、口腔或鼻腔插头等。

采用上述方案后，大量过去用这些激光在临床上获得较好疗效的病症，均可用这类非相干单色光源为新量子源制成的各种医疗器械来治疗。临床证明上述方案是可行的，这就能使激光无法推入家庭的廉价及长寿的问题得到解决，同时便于使用维修，这种非相干单色光量子医疗技术及器械的发明将产生巨大的经济和社会效益。



## 附图说明

下面是本发明的附图说明，通过下面的说明并结合以下的详细描述，可以更清楚地了解本发明，其中：

图 1 是本发明所述的量子鼻炎流感治疗器总体图

图 2 是本发明所述的量子鼻炎流感治疗器食用状态图

图 3 是本发明所述的量子育发帽总体图

图 4 是本发明所述的激光增视保健眼镜总体图

图 5 是本发明所述的量子除皱美容罩

图 6 是本发明所述的便携式量子心脑血管治疗仪放置舌下示意图

图 7a 是本发明所述的头罩式量子心脑血管治疗仪图

图 7b 是本发明所述的清脑增记面罩总图

图 8 是本发明所述的量子体表消炎贴总图

图 9 是本发明所述的量子健肾带总图

图 10 是本发明所述的量子护心带总图

图 11 是本发明所述的量子止咳带总图

图 12 是本发明所述的量子丰乳罩总图

图 13 是本发明所述的量子四种腔内消炎贴人体使用状态图

图 14 是本发明所述的量子氙带总示图

图 15 是本发明所述的量子痔带总图

图 16 是本发明所述的量子护膝图

图 17 是本发明所述的量子骨科消炎贴

## 详细说明

下面对本发明所述的各种光量子治疗仪进行详细描述：

1. 一种量子鼻炎流感治疗器，包括鼻架、量子源、鼻腔插头、量子插座、电源盒、紧固带、穴位光针等，其特征在于：所述量子源采用能达到医疗所需光功率密度且取代相干激光光源的非相干单色光源，该非相干单色光源是由 LED950/近红外量子光源构成，光针照射穴位通常取鼻通穴，加插鼻腔量子源光照鼻腔起到加速血液循环，增加消炎能力，可加速治疗鼻炎。采用上述方案后，该量子鼻炎流感治疗器的疗效与同类激光治疗器相同；当该治疗器用于治疗流感，尤其早期流感病毒刚刚浸入呼吸道停留在鼻腔内时，图 1 中光量子源 2 发出近红外光，本身具有温热效应及干燥作用，流感病毒在  $42^{\circ}\text{C}\sim 52^{\circ}\text{C}$  的干燥光照条件下灭活，因此本发明的鼻炎流感治疗器可将流感病毒

直接消灭，从而治疗流感。

2. 一种量子育法帽，包括帽壳、软弹垫、LED660/红量子源、反光板、电插头、电源盒等组成，采用与 He-Ne 激光相似的光源设计成帽式，患者戴于头部，可以治疗秃头。

3. 一种激光增视保健眼镜，是一种非手术法治疗近视、弱近、斜视及老视等屈光不正眼科病症的医疗器械。该镜通过激光增视法、压抑法、红光闪烁法和红光穴位照射——光针法等几种治疗方法的综合作用，达到增视保健的目的。

此外采用红光照射眼区对改善脑供血供氧也大有益处，尤其中老年眼保健可延缓老视眼的发展，是防治心脑血管病的保健器械。

4. 一种量子除皱美容罩，利用  $\phi$  5LED 660/红发光管发出的光照，改善皮下微循环，同时还能激化下胶原细胞，从而达到消除皱纹面部光滑美容的目的，与采用弱激光如 He-Ne 激光美容仪相比，本发明疗效快、持久便于推广家庭使用。

5. 一种量子无损血氧仪，采用无损伤自血光量子法增加血液携氧能力达到治疗心脑血管缺血缺氧疾病的目的；可以作成便携式，也可以采用头罩式，还可以采用面罩式；便携式放于患者舌下，通过作用于舌下血液及淋巴起到治疗作用，而面罩式和头罩式主要通过作用于穴位及皮下血液起到治疗作用，也可连接有便携式的头 31，同时通过作用于舌下血液及淋巴起到治疗作用。舌下量子源和穴位量子源采用能达到医疗所需光功率密度且取代相干激光的光源，该非相干单色光源是使其一组发光光斑尽量重叠使其功率密度足够大与 He-Ne 激光或半导体激光血疗的功率密度相仿，这种量子源是近几年新产品，其单色性也很好，主峰 660 毫微米正好落在血液吸收峰内，如图 6，舌下血液及淋巴丰富且粘膜光透过性很好，几乎与直接内照射血管相似，这种对人体无损伤无痛苦的自血疗法采用这种非相干单色光源取代激光，患者很容易接受。如果患者伴有心区疼痛，还可结合用图 10 的量子护心带配合使用，如果治疗脑缺氧可加吸氧，对于脑外伤或一氧化碳中毒的植物人可加用本发明图 4 的“激光增视镜”对视觉与脑神经刺激加速唤醒。对于心脏病患者可代替救心丸随身携带。对于中老年预防心脑血管病的发生也起保健的作用。

本发明的量子血氧仪对患者无损治疗，对于中老年提高血氧含量，预防心脑血管疾病也起到保健之功效。对青少年学生用脑过量引起的头昏脑胀、多梦、记忆减退、视力下降等症有清脑增视之功能。

本实用新型适应症：

- \* 急性脑血栓（有效率 94%-100%）
- \* 半年以上陈旧脑血栓（显效率 20.3%）
- \* 血稠 \* 冠心病 \* 感染
- \* 一氧化碳中毒，脑外伤，植物人初期苏醒、截瘫、烧伤。
- \* 促进唾液分泌消化酶被激活，有助消化功能治疗消化道溃疡。
- \* 量子照射造成了富氧环境，有利于改善肺换气效果治疗肺心病、气管炎。

采用上述方案后，量子无损血氧疗仪的疗效与激光疗仪相同，但克服了激光疗仪对患者有损伤的不足，由于无损疗仪是采用对体表粘膜量子血液输注，即对患者无损充氧，如对头部、舌下注光能迅速提高血氧饱和度，改善心脑血管缺氧，能提高心脑血管组织对氧的利用，能降低血粘度、降血脂、防止血栓发生，同时对浅表粘膜如舌下、眼眦等、淋巴丰富的地方，还能提高机体免疫功能。

6. 一种量子消炎贴，可以用兰、红、近红外三种单色光为量子源制成消炎贴，分别用于治疗皮肤炎症、溃疡、刀口不愈合、烧伤、烫伤、冻伤浅表炎、关节、骨质增生、腰疾劳损、颈椎病、以及大面积内脏疾病引发的疼痛如阑尾炎、肾炎、冠心病心绞痛等。

此外本发明的光量子疗法还可以用于制备量子健肾带、量子护心带、量子止咳带、量子丰乳罩、量子腔内消炎贴、量子氩带、量子痔带等。

下面是本发明的实施例，所述的实施例是用于说明本发明，而不是限定本发明。

### 实施例 1

由图 1 和图 2 所示，患者戴上该治疗器，鼻架 1 置于鼻部，紧固带 6 套于耳部，穴位光针 7 对正鼻通穴，量子插座 4 与电源盒 5 接通，然后将鼻腔插头 3 及固定在其上面的量子源 2 放入鼻腔内，打开电源盒 5 接通电源，即开始治疗。该治疗器用于治疗流感，尤其早期流感病毒刚刚浸入呼吸道停留在鼻腔时，图 1 和图 2 中的穴位光针 7 照射鼻通穴，加插鼻腔量子源 2 光照鼻腔即刻加速血液循环，增加消炎能力，加速鼻炎治疗，量子源 2 发出近红外光本身具有温热效应及干燥作用，流感病毒在 42℃—52℃ 的干燥光照射下，可将流感病毒直接消炎，从而治疗流感。

## 实施例 2

脱发是一种毛囊疾病,多因其血养供应不上而引发毛发脱落造成斑秃、早秃、全秃等,现有技术之中临床采用 He-Ne 激光照射病灶区可改善头皮下血液循环,从而为营养不良的毛囊送入充足的营养,毛发也就随之而生。本发明采用与 He-Ne 激光相似的光源设计成帽式,患者戴于头部,新光源 10 由 LED660/红 $\phi$ 5 多支组成,帽内按头型分前区(1区)、中区(2区)、后区(3区)、左区、右区(4、5区)五部分,患者可按自己脱发区开启相应电源盒 13 上的开关照射,帽内各区光照片与帽壳 8 间有弹性软垫 9 和反光板 11,可保护不同头型患者戴帽后光疗效果一样,帽壳的底部有插头 12,可拆卸,每天一次,每次 20-50 分钟,14 天即有新发长出,若配用蒽林霜( $C_{14}H_{10}$  0.1%)外涂患处后再用此帽效果更好。

## 实施例 3

激光增视保健眼镜具有下述部件及协同作用,如图 4 所示:

A、激光增视:采用小功率光直接照射眼底黄斑中心凹部,可引发眼底锥细胞的兴奋,该镜采用 1 毫瓦红色半导体激光器 15 通过旋转定位片 16 使其弱视患者眼底中心凹部分接受强红光刺激 5 分钟,每天照一次,可大大增强弱视眼的视力。

B、压抑增视:眼科治疗弱视常采用一对凸透镜让弱视眼通过凸透镜看近物,而看远则用健眼,称为压抑法,该镜采用一对+3D 凸透镜 18 治疗弱视,而对于近视患者又兼作雾式疗法,用于缓解眼肌的疲劳,同时又是真假近视的自检器。

C、红光闪烁增视:采用红灯泡开关闪烁是治疗改善弱视患者常用的方法,该镜的红色闪光灯 19 及遮挡片 20 即是一组 LED $\phi$ 5 660/红的半导体发光管脉冲闪烁光源 17,对弱视眼进行红光闪烁疗法进行增视治疗。

D、红光穴位照射——光针法:

该镜 14 取眼区上明穴、睛明穴、承泣穴用 LED660/红半导体发光管 17 照射起到激光光针的增视作用。图中的 21 为电源盒。

## 实施例 4

图 5 是量子除皱美容罩,包括外壳 22,额头软垫 23,内反光罩 24,扣带 25, $\phi$ 5LED 660/红发光管 26,发光管座 27,下巴软垫 28,电源盒 29,和接线插头组 30;采用多支红色半导体发光管对其抬头纹、上下眼袋、眼角鱼尾纹、鼻翼面部及嘴角纹同时光照除皱。

### 实施例 5

将由 LED660/红 4 支发光管 32 构成的非相干单色光源，植于一医用无毒塑料块 31 内，放于患者舌下，如图 6 所示，无毒塑料块 31 通过一口腔引出线 34 与电源盒 33 相连，开启电源开关，舌下量子源发出能达到医疗所需光功率密度且取代相干激光的光源，该非相干单色光源是使其一组发光光斑尽量重叠使其功率密度足够大与 He-Ne 激光或半导体激光血疗的功率密度相仿，其单色性也很好，主峰 660 毫微米正好落在血液吸收峰内，将发光管，舌下血液及淋巴丰富且粘膜光透过性很好，几乎与直接内照射血管相似，对人体无损伤无痛苦。

### 实施例 6

见图 7a 患者戴上头罩 36，并系好头罩扣带 35，头罩上的穴位量子源 37 置于头部健脑的穴位照射，以睛明穴对准为正确，同时将塑料块 31 上的舌下量子源 32 的触头含于舌下，让光照舌根粘膜，将 220V/3V 电源盒 33 接通电源，打开 220V/3V 电源盒 33 的定时开关 39 并连接 3V 电插头 38，即可定时开始工作，每次定时 20 分钟，额头垫 40 可以起固定作用，休息几分钟再定时一次，共 40 分/天，14 天为一疗程，由于光量子可透过皮表及粘膜进入血液，达到治疗作用，血氧含量等指标会有明显好转，并有健脑增记的效果，上述穴位量子源 37 和舌下量子源 32 由 LED660/红 4 支发光管构成。

### 实施例 7

同实施例 6，只是不含有量子源 31 上的舌下量子源 32。

### 实施例 8

LED660/红半导体发光二极管 42 ( $\phi 5$ ) 二支装于面罩口角二侧，见图 7b，使其二管发光光斑重叠，加套无毒透明塑管，同时面罩内还加有与穴位相应的几组发光管如 45 和穴位光管座 46，下颚处有下颚垫 44，额头有额头垫 40，带有光源的无毒塑料块 31 可以放置于口腔内，插座 43 接电源盒和面罩 41，治疗时将面罩套到面部，将口角透明塑管含于舌下，面罩内穴位光照还可增加血液吸收及皮下微循环，达到清脑增加记忆的功效。

### 实施例 9

本发明的量子消炎贴，采用不同波长光对体表照射其透过深度不同，因此治疗不同疾病应对应选取不同的波长单色性好的光用于光疗。

图 8 所示量子体表消炎贴，包括园形贴片 47，LED660/红发光二

极管 48, 发光管座 49, 长形贴片 50 及电源盒, 用 LED660/红组成片状、圆状及条状, 其主峰 660 毫微米, 每支 LED 功率可达 5mw。组合用照患部或穴位治疗方法同 He-Ne 激光临临床病症, 治疗皮肤炎症、溃疡、刀口不愈合、烧伤、烫伤、冻伤浅表炎。

#### 实施例 10

对于关节、骨质增生、腰疾劳损、颈椎病则采用兰色 LED450/兰组成各种病的对应形状的贴片, 其它同实施例 9。

#### 实施例 11

对于大面积内脏疾痛引发的疼痛如阑尾炎、肾炎、冠心病心绞痛则采用 LED950/近红外发光管组成穴位或痛点区形状的消炎止痛贴片, 其它同实施例 9。

#### 实施例 12

中老年肾虚, 尤其性生活后症状更加明显腰酸疼乏力, 量子健肾带光源 53 是以近红外 LED950/半导体发光管为量子源照射对应疼痛区肾俞穴照射, 即缓解牵扯痛又起到光疗及光针灸的健肾功效。

产品骨架形是按人体一般腰区设计, 包括腰带 51, 腰型骨架 52, 量子源 LED950/近红外 53 及电源盒和搭扣等, 见图 9, 便于与对应的肾俞穴及肾区牵扯痛相对应。

#### 实施例 13

图 10 为量子护心带, 包括量子源 54, 背带骨架 55, 穴位光针组(对心愈穴)56, 腰带(附尼龙搭扣)59, 松紧带 57, 电源插口 58 及电源盒。量子护心带用于冠心病、心绞痛等心血管患者因供血不足引发左部心背牵扯痛, 近红外单色光量子源 54 可有效扩张血管, 改善供养条件, 同时其灸疗可缓解心及背区牵扯痛, 从而缓解痛苦, 护心带分 ABCDE 五个区按患者的需要开启对应电源 ABCDE 五档开关。

#### 实施例 14

图 11 为量子止咳带, 包括量子止咳带脖套 60, 量子源 61, 骨架 6 穴位组量子源 63, 掀扣开关 64 及电源盒。

咳嗽多因支气管痉挛造成, 量子光源 61 采用近红外光量子源分布于主气管两侧并予天突主穴加一组 3 只量子源照射, 可很快缓解其痉挛, 从而达到止咳平喘之功效, 量子止咳带制成脖套式, 背面开口用尼龙搭扣调节松紧度, 天突穴位于脖下与锁骨交叉窝处, 此处的穴位量子源组为止咳带照射中心点。

### 实施例 15

图 12 为量子丰乳罩, 包括左右各 6 支的量子源 65, 丰乳罩 66, 电源插头 67, 弹性桥架 68 及电源盒。其量子源 65 发出的近红外光量子对于改善皮下微循环, 改善皮下营养吸收状态, 其温热作用尚可起到血管扩张乳房丰满的物理疗效。可与乳罩配用。

图 13 所示是以上四种腔内消炎贴在人体的使用状态, 图中标号:

量子止咳带 60, 量子丰乳罩 66, 量子护心带 55, 量子健肾带 51。

### 实施例 16

图 14 为量子氙带, 包括量子源 69, 弹性夹 70, 量子氙顶头 71, 掀扣插头开关 72, 腰带 73, 脐氙顶头 74 及电源盒。

通常外用氙夹对于治疗腹氙有较好疗效, 但需整日夹固, 采用近红外量子源制成的氙带每天仅需早晚戴二次, 且由于近红外光量子的作用不仅对腹氙且对脐氙、股氙均有疗程短, 见效快, 无痛苦的优点。

### 实施例 17

图 15 所示量子痔带, 采用两组近红外量子源, 组肚脐量子源组 75 通过腰带 77 贴神阙穴(肚脐), 一组组肛痔量子源 79 通过股带贴肛门, 带上有掀扣开关 76。

### 实施例 18

图 16 是量子护膝贴, 采用两种光量子源, 分别为 LED950/近红外光源 80 和 LED450/兰半导体光源组 81 以及电源盒组成护膝 82。

其中对关节炎膝眼穴位作深部穴位照射是仿照临床  $\text{Ar}^+$ 480 兰激光在临床骨科深层照射消炎消肿的基理, 兰光比红光透过深, 而牵扯痛区采用二排近红外光源  $\phi$  3LED950/近红外绅化镓半导体光源照射有缓解疼痛局部消炎消肿之功效。

采用上述方式还可以制成量子颈椎消炎带 83 及量子肩周炎治疗带 84 及量子跟骨骨刺消炎贴 85 等系列产品。参见骨科消炎贴使用状态见图 17。

## 权 利 要 求

1. 一种光量子源医疗技术, 其特征在于: 采用能达到医疗所需的光功率密度的非相干单色光源取代相干的激光光源的光疗方法。

2. 根据权利要求 1 所述的光量子源医疗技术, 其特征在于: 采用下述廉价长寿命的非相干单色光源:

1) 近红外光量子源: 950/近红外发光材料: CaAs 半导体 LED 发光二极管, 其主峰 950 毫微米, 单支发光管发光功率 50-100 毫瓦, 可取代半导体激光器为新型非相干近红外医疗用单色光源;

2) 红光量子源: 660/红色发光材料: CaAlAs 半导体 LED 发光二极管, 其主峰 660 毫微米, 发光管单支光功率 5-10 毫瓦, 可取代 He-Ne 激光用于医疗用单色光源;

3) 兰光量子源: 450/兰色 发光材料:  $Al_2O_3$ , LED450/兰色, 其发光主峰 450 毫微米, 发光管单支功率 5 毫瓦, 多支组合可代替  $Ar^+$  激光用于医用单色光源。

3. 根据权利要求 2 所述的光量子源医疗技术, 其特征在于: 其发光管光谱半宽度一般为几十毫微米, 单色性完全可以达到医疗的要求及由电源、光量子源和治疗器组成的医疗器械。

4. 一种光量子源医疗器械系列, 其特征在于: 用能达到医疗所需的光功率密度的非相干单色光源作为光量子源, 并配以电源和治疗器组成医疗器械, 用以取代相干的激光光源及医疗器械。

5. 根据权利要求 4 所述的光量子源医疗器械, 其特征在于: 采用非相干单色光量子光源制成以下系列量子医疗器械:

1) 量子鼻炎流感治疗器

2) 量子育发帽

3) 激光增视保健眼镜

4) 量子除皱美容面罩

5) 量子心脑血管氧疗器

6) 量子消炎贴, 包括:

6A) 量子体表消炎贴;

6B) 量子腔内消炎贴: 量子键肾带、量子护心带、量子止咳带、量子丰乳罩、量子氙带、量子痔带,

6C) 骨科消炎贴: 量子关节炎护膝贴、量子颈椎消炎贴、量子肩周消炎贴、量子跟骨骨刺消炎贴。



6. 根据权利要求 5 所述的医疗器械, 其特征在于: 所述的医疗器械包括量子光源、紧固带、穴位光针、量子插座、电源盒、口腔或鼻腔插头等。

7. 根据权利要求 4 所述的光量子源医疗器械, 其特征在于: 所述的量子心脑血管氧疗器可以作成便携式, 也可以采用头罩式, 还可以采用面罩式。

8. 根据权利要求 4 所述的光量子源医疗器械, 其特征在于: 所述的便携式量子心脑血管氧疗器是将由 LED660/红 4 支发光管 32 构成的非相干单色光源, 植于一医用无毒塑料块 31 内, 使用时放于患者舌下, 无毒塑料块 31 通过一口腔引出线 34 与电源盒 33 相连, 开启电源开关, 舌下量子源发出能达到医疗所需光功率密度且取代相干激光的光源, 该非相干单色光源是使其一组发光光斑尽量重叠使其功率密度足够大与 He-Ne 激光或半导体激光血疗的功率密度相仿, 其单色性也很好, 主峰 660 毫微米正好落在血液吸收峰内, 将发光管, 舌下血液及淋巴丰富且粘膜光透过性很好, 几乎与直接内照射血管相似, 对人体无损伤无痛苦。

9. 根据权利要求 4 所述的光量子源医疗器械, 其特征在于: 所述的头罩式量子心脑血管氧疗器包括头罩 36、电源盒 33、开关 39、电插头 38 及头罩扣带 35, 头罩上由 LED660/红 4 支发光管构成的穴位量子源 37 置于头部健脑的穴位照射, 以睛明穴对准为正确。

10. 根据权利要求 4 所述的光量子源医疗器械, 其特征在于: 所述的面罩式量子心脑血管氧疗器包括 LED660/红  $\phi$  5 半导体发光二极管 42 二支装于面罩口角二侧, 使其二管发光光斑重叠, 加套无毒透明塑管, 同时面罩内还加有与穴位相应的几组发光管如 45 和穴位光管座 46, 下颚处有下颚垫 44, 额头有额头垫 40, 插座 43 接电源盒和面罩 41, 治疗时将面罩套到面部, 面罩内穴位光照还可增加血液吸收及皮下微循环, 达到清脑增加记忆的功效。

11. 根据权利要求 9 或 10 所述的光量子源医疗器械, 其特征在于: 所述的面罩式或头罩式量子心脑血管氧疗器进一步包括一带有 LED660/红 4 支发光管构成量子光源的无毒塑料块 31 可以放置于口腔内。

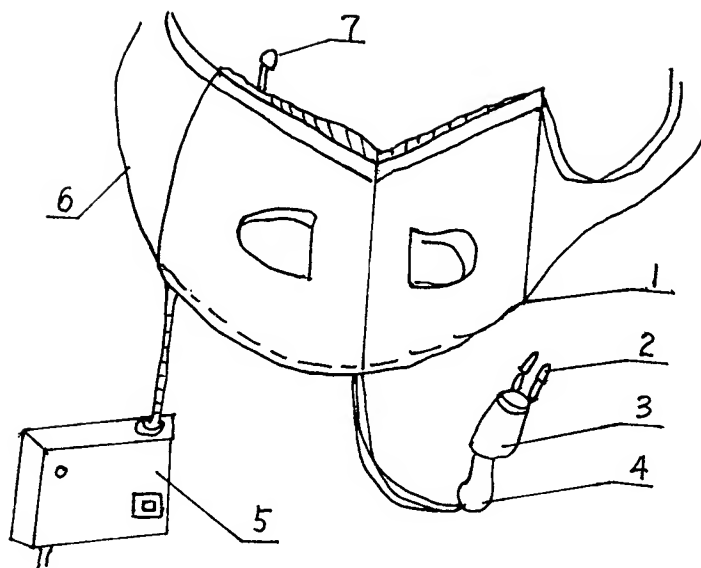


图 1



图 2

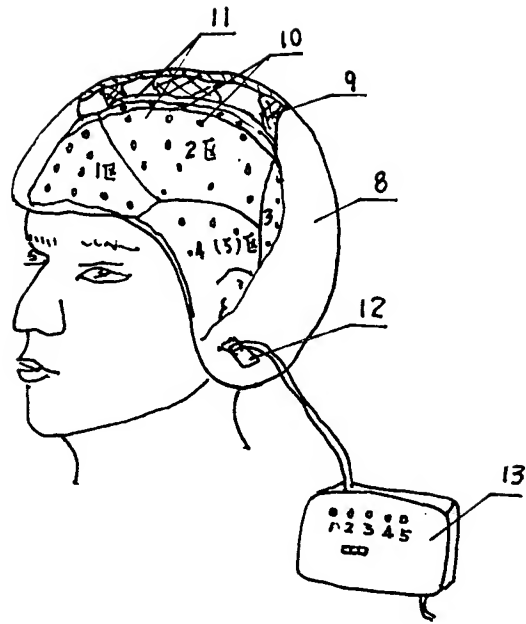


图 3

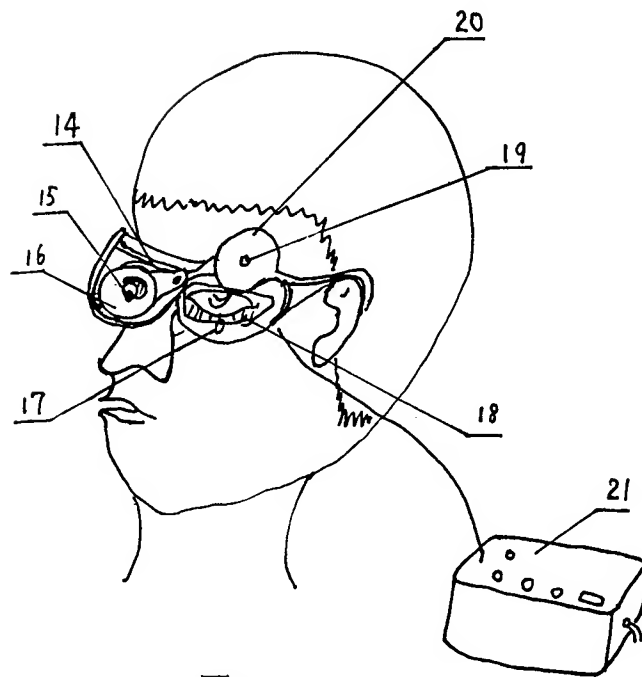


图 4

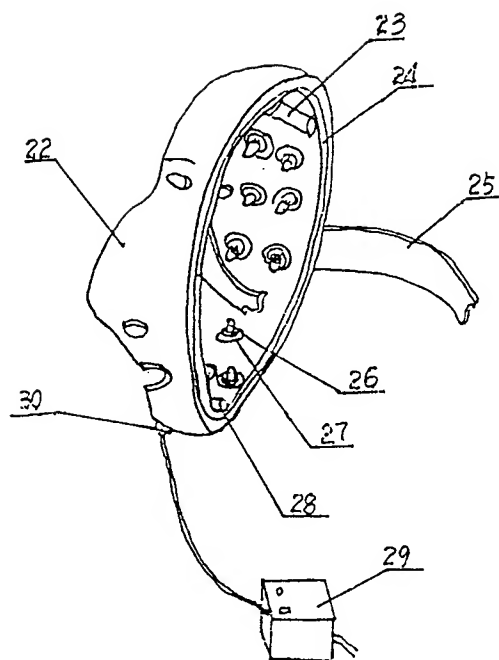


图 5

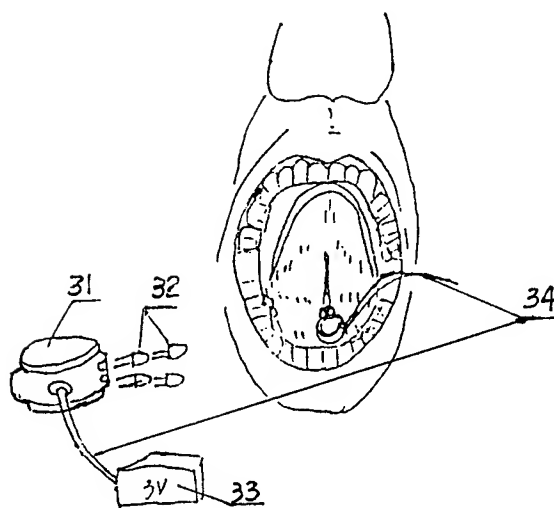


图 6

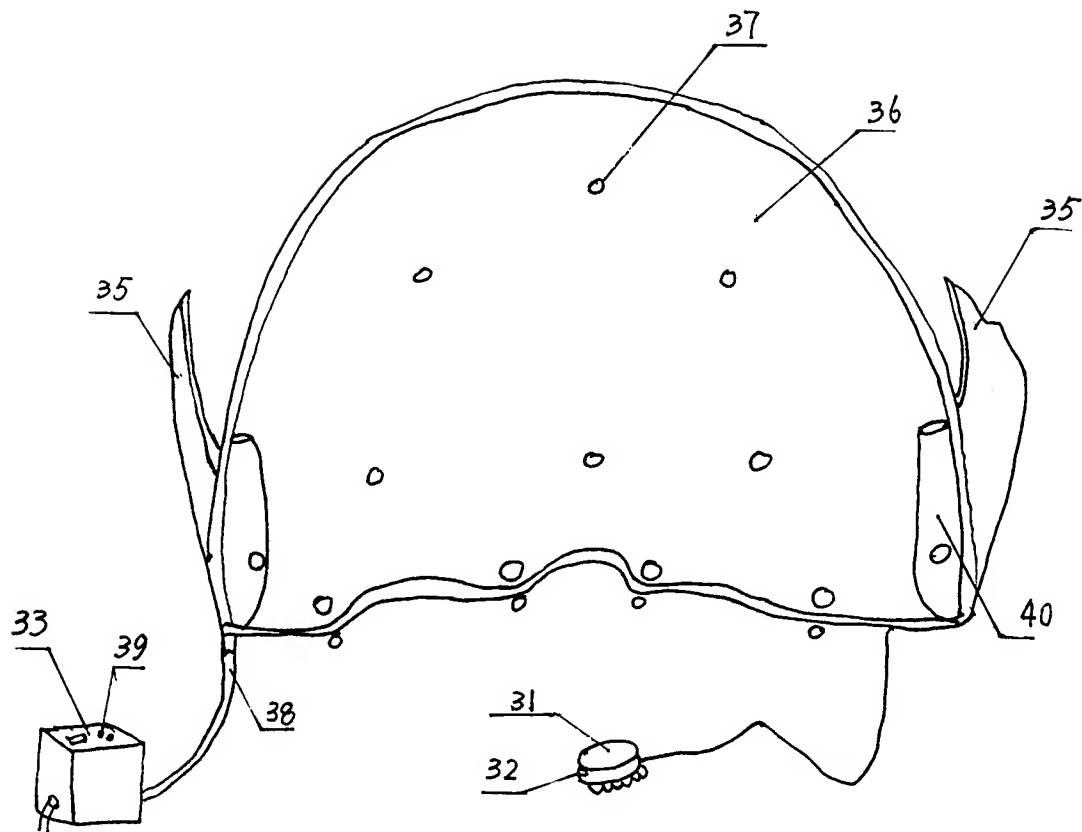


图 7a

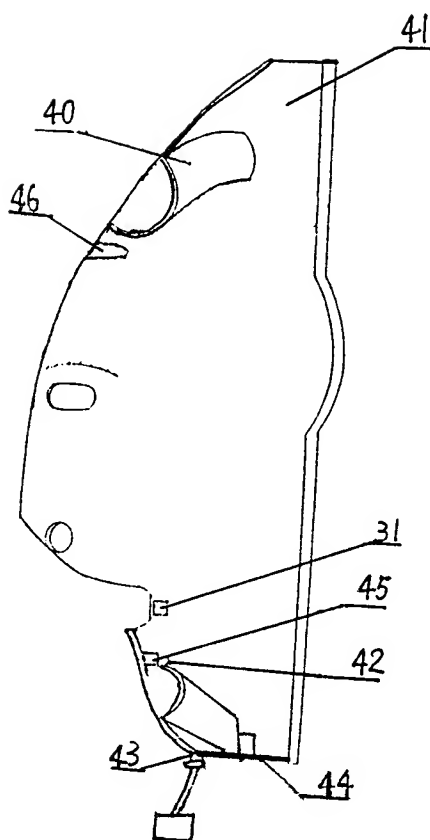


图 7b

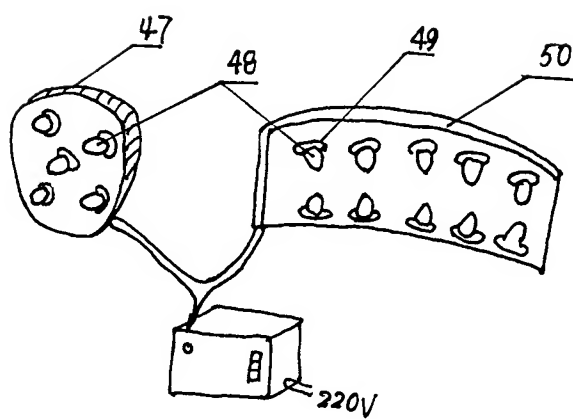


图 8

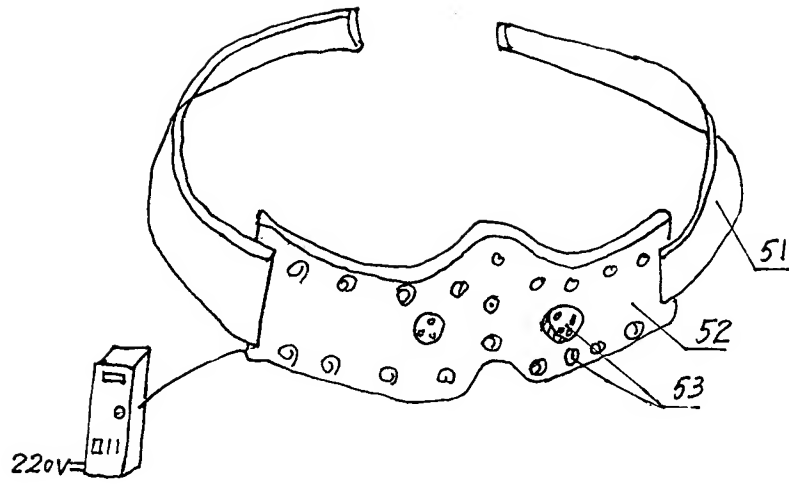


图 9

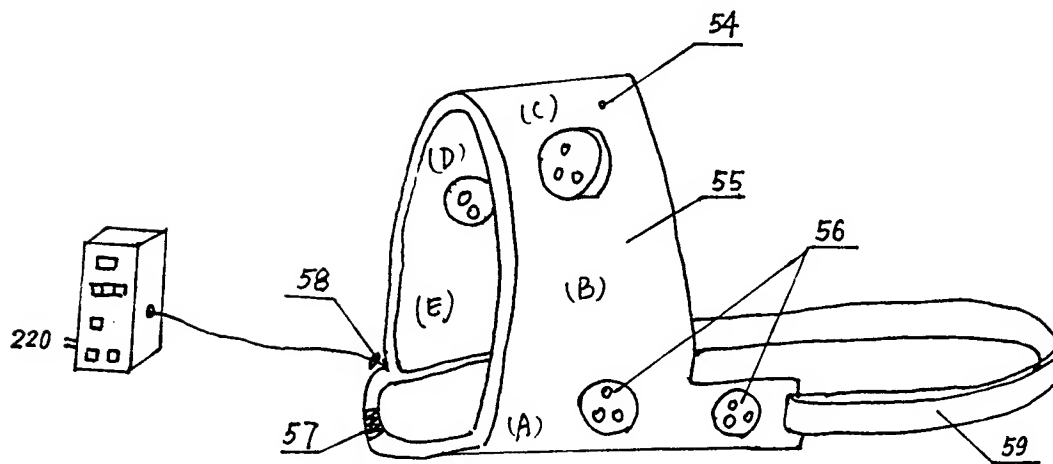


图 10

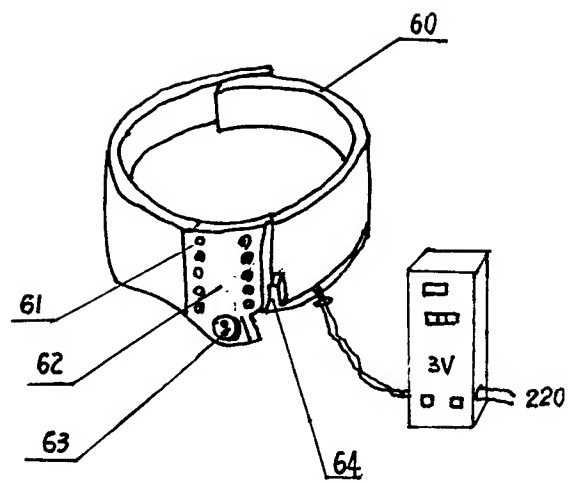


图 11

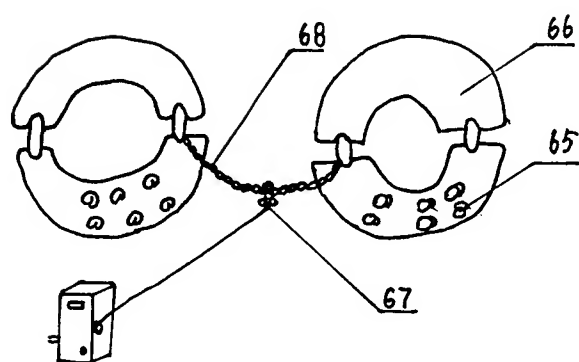


图 12



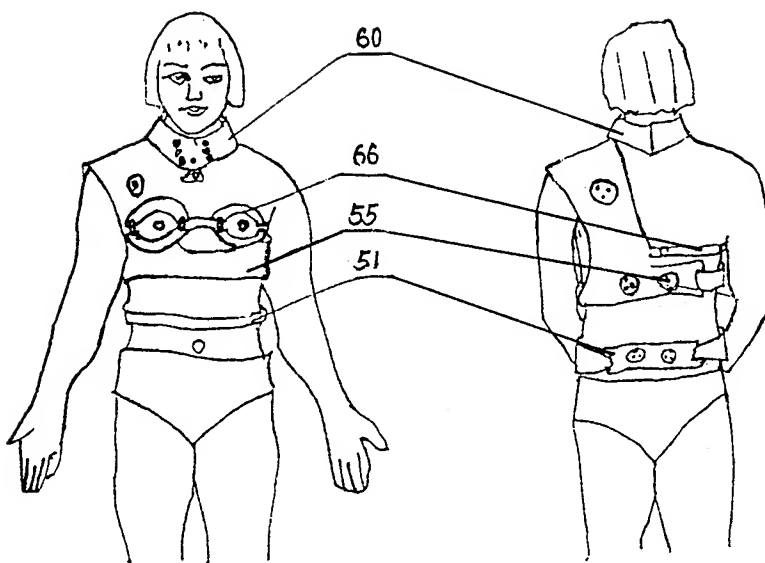


图 13

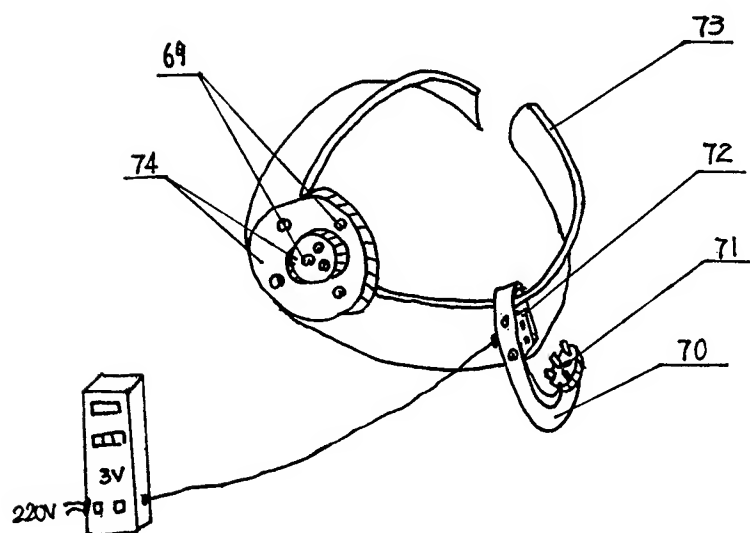


图 14

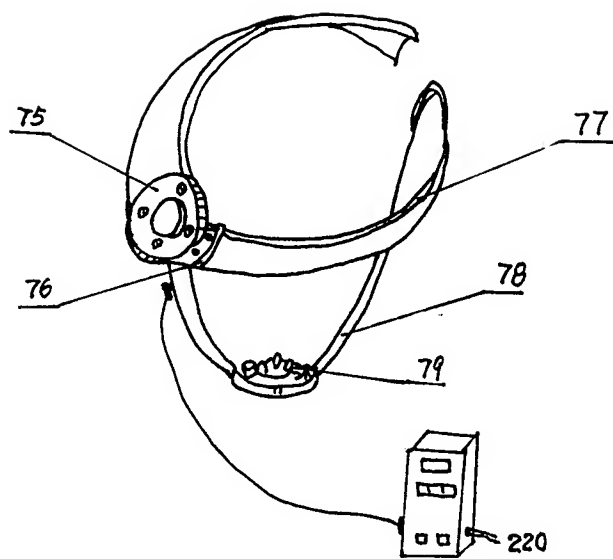


图 15

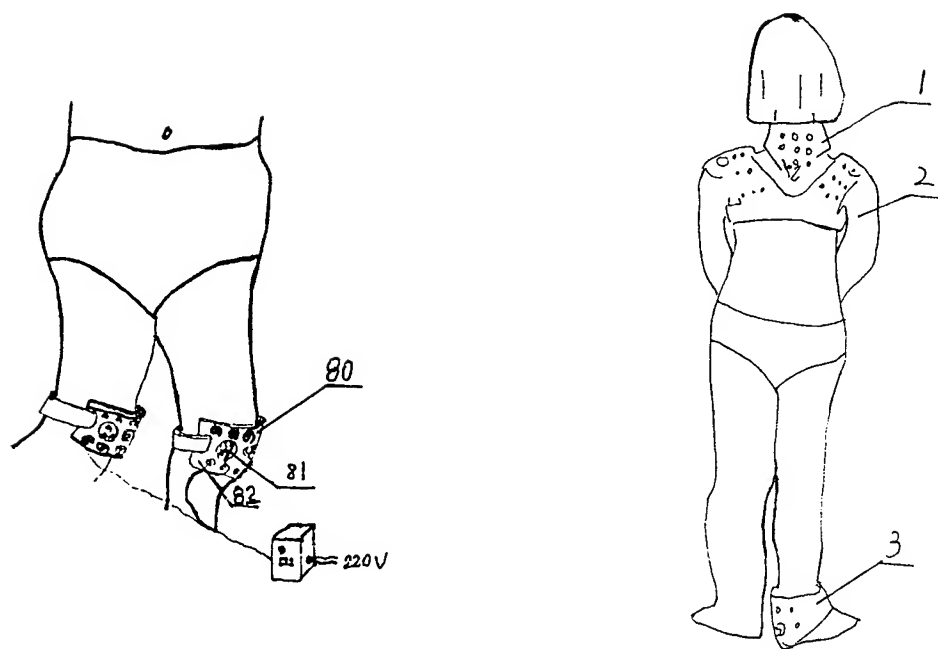


图 16

图 17

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/CN00/00014

## A. CLASSIFICATION OF SUBJECT MATTER

IPC<sup>7</sup> A61N5/067

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC<sup>7</sup> A61N5/067, A61N5/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CN

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US-A-5800479(Biolight Patent Holding AB, Danderyd, Sweden), 01.Sep.1998(01.09.1998), Abstract	1,4
A	CN-1199603A(ZHU, JiLin), 25.Nov.1998(25.11.1998), The whole document	1-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search  
24.Apr..2000(24.4.2000)

Date of mailing of the international search report  
**11 May 2000 (11.05.00)**

Name and mailing address of the ISA/CN  
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SONG, Yanqin  
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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
PCT/CN00/00014

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US5800479	01.09.98	SE-9402679	21.07.95
		SE-9400153	21.07.95
		WO-9519809	27.07.95
		CA-2181346	27.07.95
		CA-2181345	27.07.95
		AU-1549595	08.08.95
CN1199603A	25.11.98	None	

## 国际检索报告

国际申请号

PCT/CN00/00014

## A. 主题的分类

IPC<sup>7</sup> A61N5/067

按照国际专利分类表(IPC)或者同时按照国家分类和 IPC 两种分类

## B. 检索领域

检索的最低限度文献(标明分类体系和分类号)

IPC<sup>7</sup> A61N5/067, A61N5/06

包含在检索领域中的除最低限度文献以外的检索文献

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在国际检索时查阅的电子数据库(数据库的名称和, 如果实际可行的, 使用的检索词)

## C. 相关文件

类 型*	引用文件, 必要时, 指明相关段落	相关的权利要求编号
X	US-5800497A (Biolight Patent Holding AB, Danderyd, Sweden), 01.9 月 1998 (01.09.98), 摘要	1 , 4
A	CN-1199603A (朱吉林), 25.11 月 1998 (25.11.98), 全文	1-11

☐ 其余文件在 C 栏的续页中列出。☒ 见同族专利附件。

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国际检索实际完成的日期

24.4 月.2000 (24.4.2000)

国际检索报告邮寄日期

11. 5月 2000 (11.05.00)

国际检索单位名称和邮寄地址

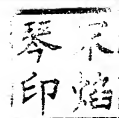
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宋焰琴



电话号码: 86-10-62093192

**国际检索报告**  
关于同族专利成员的情报

国际申请号

PCT/CN00/00014

检索报告中引用的 专利文件	公布日期	同族专利成员	公布日期
US5800479	01.09.98	SE 9402679	21.07.95
		SE9400153	21.07.95
		WO9519809	27.07.95
		CA2181346	27.07.95
		CA2181345	27.07.95
		AU1549595	08.08.95
CN1199603	25.11.98	无	



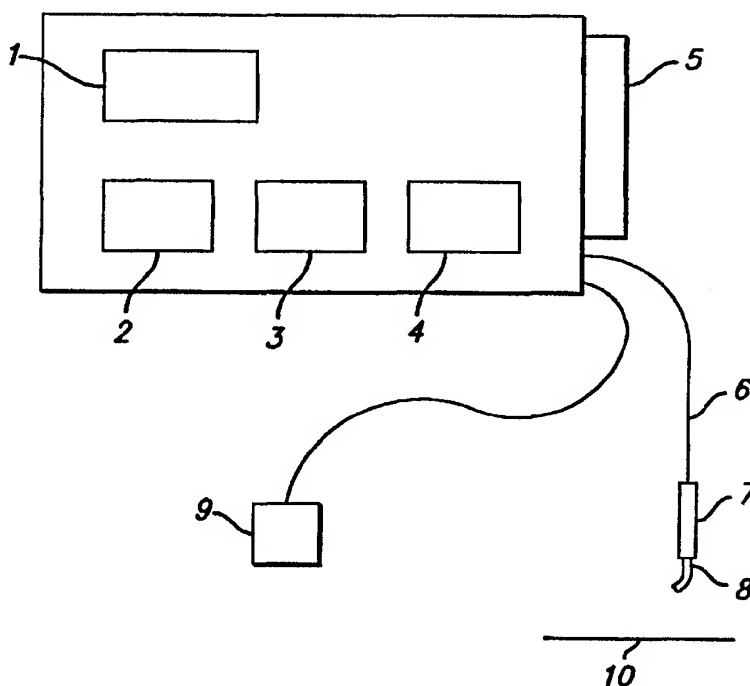
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : <b>A61B 18/00</b>		<b>A1</b>	(11) International Publication Number: <b>WO 00/44294</b>
			(43) International Publication Date: 3 August 2000 (03.08.00)
(21) International Application Number: PCT/US00/02136 (22) International Filing Date: 28 January 2000 (28.01.00) (30) Priority Data: 60/117,942                      29 January 1999 (29.01.99)                      US (71) Applicant (for all designated States except US): WELCH AL- LYN, INC. [US/US]; 4341 State Street Road, Skaneateles Falls, NY 13153 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): KUTSCH, V., Kim [US/US]; 1155 Twin Hills Drive, Jefferson, OR 97352 (US). McEACHERN, Richard, D. [US/US]; 1360 Dexter Road, Escondido, CA 92029 (US). (74) Agents: BRUEGGEMANN, James, R. et al.; Sheppard Mullin Richter & Hampton LLP, 333 South Hope Street, Los Angeles, CA 90071 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>	

(54) Title: APPARATUS AND METHOD OF PHOTO-SPECIFIC TISSUE TREATMENT

## (57) Abstract

An apparatus and related method are disclosed for directing a continuous or pulsed, polychromatic light beam through a hand-held light guide at a target biological tissue, as part of a health-related treatment in medicine or dentistry. The non-laser polychromatic light beam can be pulsed at a duration and duty cycle selected to provide optimal heating of the target issue, e.g., to temperatures in the range of 37° to 175 °C, while allowing the tissue to undergo a thermal relaxation response between successive pulses. The treatment delivers a photo-specific energy density in the range of 10 to 5000 watts/cm<sup>2</sup>, selected to achieve the desired treatment. In the case of dental procedures on hard dental tissue, such treatments can include tooth bleaching, curing of dental composite materials, detecting of caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty, ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination.



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## APPARATUS AND METHOD OF PHOTO-SPECIFIC TISSUE TREATMENT

### BACKGROUND OF THE INVENTION

The present invention relates generally to the use of non-coherent  
5 light in various health-related fields such as medicine, dentistry, and veterinary  
medicine. More specifically, the invention relates to the use of pulsed light to  
treat biological tissue.

Laser surgery is commonplace in modern dental practice. Reasons  
for laser use include minimization of both trauma during surgery and post-  
10 operative pain to the patient. Laser light has been used to stop bleeding, to cut  
tissue, to weld, and to coagulate tissue. This light/tissue interaction can cause  
non-specific photo-thermal changes that can result in reflection, absorption,  
scattering, and transmission of the light by the tissue. Details can be found in a  
reference entitled *Lasers in Dentistry*, by L.J. Miserendino and R.M. Pick,  
15 Quintessence Books, 1995.

Lasers can function to concentrate high densities of light energy on  
a very small spot. Very little of this light is diverged because of the coherent and  
collimated nature of laser light.

Many patents have issued in the field of using laser light as a tool  
20 in medical applications. Among these include ophthalmic treatments for macular  
degeneration, retinal attachment, and cataract removal. Patents also have issued  
relating to the use of laser light for hair removal, dermatology treatments, scar  
removal, and facial rejuvenation.

As one example, U.S. Patent No. 5,435,724 to Goodman et al.  
25 describes dental procedures and apparatus using pulsed ultraviolet light.

Specifically, ultraviolet light pulses are used to selectively etch both hard and soft tissue in dental procedures. Distinct ablation, or vaporization, thresholds exist for each type of tissue. This allows the dentist to perform both hard and soft tissue procedures without damaging healthy enamel, dentin, or the like.

5                   Laser light has been widely applied in dentistry for soft tissue treatment and surgery. Laser light customarily is delivered via optical fibers, hollow waveguides, or articulated arms. Dental soft tissue treatment may include hemostasis, coagulation, ablation, and vaporization of soft oral tissue. Lasers have been used for periodontal treatment, gingiva surgery, frenum  
10 surgery, and the like. In fact, laser treatment of maxillary midline frenectomy is becoming a standard of care. Post-operative pain is rare when lasers are used for this procedure.

                    Medical, dental and veterinary procedures that use laser light function by raising tissue temperature. The table below indicates the effects on  
15 tissue as a function of temperature and energy.

TABLE 1

<u>Tissue Effect</u> <u>(Watts/cm<sup>2</sup>)</u>	<u>Temp (degrees C)</u>	<u>Energy</u>
Hyperthermia	37-50	<10
20 Coagulation	50-60	100-500
Welding	70-80	500
Vaporization	90-100	500-1,000
Carbonization	100-150	1,000-5,000
Rapid Cutting	>175	>5,000

One advantage of laser soft tissue treatment is that the heat generated kills bacteria. It also provides a bloodless operating field, which results in less post-operative inflammation and pain.

5 Most laser procedures are contact, or near contact, surgeries, making the collimation feature not critical. In addition, laser light loses its coherent upon passage through a fiber optic. Since most dental lasers are delivered through fiber optics, the coherent characteristic is not necessary either. The important and necessary feature of the delivered light for medical, dental and veterinary procedures is its energy density.

10 In the past, conventional photo-thermal treatment of oral soft tissue has been accomplished using only certain approved lasers. These include visible light lasers such as argon and infrared lasers such as aluminum gallium arsenide diode, Nd:YAG, Ho:YAG, Er:YAG, and CO<sub>2</sub>. These devices are very efficient in providing the desired photo-thermal effects on soft tissue.

15 According to dental and medical authorities, the advantages of using lasers, particularly CO<sub>2</sub> lasers, in oral surgery, include excellent hemostasis, improved viability during the procedure, minimal damage to adjacent tissue, reduced postoperative swelling, pain and infection, and a relative absence of scarring and wound contracture. These benefits have been attributed  
20 to the ability of the CO<sub>2</sub> laser to seal small blood vessels and lymphatics, which circumvent some of the inflammatory processes of wound healing. The CO<sub>2</sub> laser was limited in its early use by its inability to be effective in hard tissue, namely bone, enamel, cementum, and dentin.

Further work to broaden the application of lasers led to the Nd:YAG lasers in the 1980's. Research continues to develop new uses for dental lasers, for hard tissue procedures as well as various restorative procedures. Some of the procedures may be caries detection and prevention, cutting enamel, dentin, and bone, desensitization of dentin, enamel etching, osteoplasty, and ostectomy.

One drawback of these laser tools is that they are quite expensive to purchase and maintain. Also, certain lasers equipped with articulating arms are often cumbersome. Specifically, CO<sub>2</sub> lasers with articulated arms are often difficult to use for dental procedures. Additionally, the CO<sub>2</sub> laser beam is invisible. A visible He:Ne laser beam can be built coaxially, for use as an aiming device. Aiming an invisible light at soft tissue from a distance is difficult and risks adjacent tissue of being inadvertently hit by the laser beam.

The fact that lasers are monochromatic is an inherent limitation, because tissue absorption profiles are polychromatic. Because of this discrepancy, lasers offer a less than optimum and limited range of applicability in many dental and medical procedures.

Many medical, dental, and veterinary laser procedures are contact, or near contact surgeries, making the collimation feature of laser light not critical. In addition, laser light loses its coherent upon passage through a fiber optic. Since most dental lasers are delivered through fiber optics, the coherent characteristic is not necessary either. The important and necessary feature of the delivered light for medical and dental procedures is its absorption by tissue. This absorption raises the tissue temperature and causes the tissue effect.

25

Since the absorption profile for all tissues is a broad band of wavelengths, the monochromatic feature of laser light is also not necessary. In fact, more efficient transfer of energy occurs over the entire bandwidth of the absorption profile of the tissue.

5                   It should therefore be appreciated that there is a need for an improved apparatus and related method for treating biological tissue as effectively as some of the laser systems described above, but without the associated drawbacks. The present invention satisfies this need.

### SUMMARY OF THE INVENTION

10                   The present invention is embodied in an improved apparatus and related method for performing medical and/or dental procedures on a target biological tissue, with greater efficiency and without undue expense. The apparatus includes a light source for emitting a high-intensity light beam having an initial polychromatic spectrum, and a light guide having an inlet disposed at  
15                   an effective focal position of the light source and a handheld outlet end, of small cross-section, configured to be disposed in proximity to the biological tissue to be treated. A pulsing device also can be included, for pulsing the light beam emitted by the light guide for a selected duration and duty cycle, such that the biological tissue being treated undergoes a thermal relaxation response between  
20                   successive pulses. In addition, an optical filter can be included for tailoring the spectrum of the light beam directed to the target tissue for efficient interaction with the tissue.

                  In more detailed features of the invention, the apparatus further includes an adapter selectively attachable to the outlet end of the light guide, for  
25                   directing a portion of the light beam emitted by the light guide to the biological

tissue to be treated. This adapter can be configured to carry the optical filter. Further, the pulsing device can be configured to allow an operator to independently control both the duration and the duty cycle of the successive pulses of light emitted by the apparatus. This pulsing device preferably is  
5 disposed between the light source and the light guide. The light guide preferably takes the form of an optical fiber assembly including a bundle of tightly packed optical fibers, with the inlet end of the optical fiber assembly having a diameter in the range of 1 to 2 mm.

In other more detailed features of the invention, the apparatus is  
10 configured to be suitable for use in dental procedures on hard dental tissue, including tooth bleaching, curing of dental composite materials, detecting of caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty, ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination. In such applications, the light  
15 source preferably is selected from the group consisting of halogen lamps, metal halide lamps, and plasma arc lamps, and it is configured to produce a light beam having a power level in the range of 12 to 500 watts. The polychromatic light beam directed to the biological tissue to be treated preferably has a power level of at least about 0.1 watt and includes wavelengths in the range of about 400 to  
20 750 nm, and it has a photo-specific energy density in the range of 10 to 5000 watts/cm<sup>2</sup>.

Other features and advantages of the present invention should become apparent from the following description of the preferred embodiment, taken in conjunction with the accompanying drawings, which illustrate, by way  
25 of example, the principles of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic drawing of a preferred embodiment of a photosurgery apparatus in accordance with the invention.

FIG. 2 is a more detailed diagram of the control panel portion of  
5 the photosurgery apparatus of FIG. 1.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

For the purposes of this description, the terms 'medical,' 'dental' and 'veterinary' are used interchangeably. Most of the examples will be for dental applications of the light apparatus, but it is to be understood that the soft  
10 tissue treatments could be performed on any biological tissue.

The apparatus of the invention utilizes a special non-laser light source that is capable of delivering high power densities of a narrow wavelength distribution. The apparatus can perform contact or near contact treatment of tissue. The apparatus uses non-coherent visible light transmitted through a light  
15 guide, e.g., an optical fiber assembly, a hollow or liquid-filled waveguide, or an articulated arm, to deliver sufficient light energy to the tissue to controllably increase the tissue temperature. As can be seen in the above table, the increased tissue temperature results in hyperthermia, coagulation, welding, vaporization, carbonization, or rapid cutting.

20 The light source preferably is configured to emit visible light having a plurality of wavelengths and combinations of wavelengths in the visible and near infrared regions. A preferred wavelength spectrum is in the range of

400-750 nm, and preferably centered at about 565 nm. A 100-500 micron filter delivering at least 0.1 watt of continuous or selectively pulsed light to the tissue.

The apparatus of the invention overcomes the drawbacks associated with lasers by providing an inexpensive and versatile alternative to achieve comparable photo-thermal treatment. In the present invention, metal halide lamps are used which exhibit larger arcs of light energy. To couple a significant amount of light energy into a single transmission fiber requires that the fiber be larger than 600 microns. A single fiber would be too stiff and/or fragile to be used in the desired applications of this invention. In this invention, other means are used to transmit large amounts of light energy to tissue.

The arc sizes of the metal halide lamps used in this invention are made by Welch Allyn, Inc., of Skaneateles Falls, New York, and can be easily coupled into fiber bundles between 1 mm and 2 mm in diameter. With lamp powers of between 12 watts and 500 watts, such lamps achieve efficiencies which can provide between 2 to 5 watts of power coupled into and transmitted through a fiber optic bundle. The wattage not transmitted through the fiber optic bundle is dissipated as heat.

Coupling large amounts of non-coherent energy through small single strand fiber optic cable is known. To maintain flexibility, such single fibers must be no larger than 600 microns, typically 400 microns. To accomplish this, the energy source must be a short-arc arc lamp, at power levels ranging from 12 to 500 Watts, with special large diameter focusing optics to couple the required amount of energy into the fiber. The resulting high-intensity beam can be directed by the fiber tip directly into or onto tissue to achieve rapid photo-coagulation.



In this invention, a fiber optic bundle, consisting of many individual small diameter fibers configured in a tightly packed optimal configuration at the ends, is used to transmit light energy. This results in a fiber optic bundle with diameters larger than 600 microns and extremely flexibility.

5 The end fibers are fused into solid entrance apertures of up to several inches in diameter, maintaining flexibility through the bulk of the length of the transmission cable and a relatively high transmission efficiency. Such a fiber bundle exhibits similar light transmission efficiencies as single fibers, with the exception of packing fraction losses. These losses are due to the cladding loss  
10 at the fiber entrance and they can usually be limited to not more than 30 to 35 % of the total amount of light transmitted. The increased diameter of the entrance aperture and resulting increased coupling efficiency can more than make up for this loss.

The tip of the fiber optic assembly can be a bare fiber, a sculpted  
15 tip, a tapered fiber optic bundle, a focusing handpiece, or a defocusing handpiece, depending on the spot size appropriate for the procedure to be performed. A defocused tip allows the light to spread out to a larger spot size. Focused light is used when contact surgery is being performed. Defocused light is used for illumination and for non-surgical procedures such as dental bleaching,  
20 shade matching, and curing composite dental resins. The tip of the fiber optic assembly also can connect to a cannula, for convenient use in directing the light to selected portions of the target tissue.

In this invention, the larger exit diameters for the fiber conduits (up to 600 microns), handpieces which condense the transmitted light energy into  
25 higher intensity spots are required. These handpieces may be disposable or removable to facilitate sterilization, and would consist of a lens or mirror which redirects the exiting light beam into a tightly focused spot. The lenses are either

discrete lenses spaced at an appropriate distance from the fiber exit to reduce the image size, or the end of the fiber optic cable can be figured into a focusing lens to produce the intense spot of light. Another possible approach for light delivery is to use a Selfoc<sup>TM</sup>, or gradient index lens, attached at the end of the fiber optic bundle to produce the high-intensity spot at a distance from the end of the fiber. These approaches produce a high-intensity spot capable of performing dental, medical, and veterinary procedures on biological tissue with light at a distance of several millimeters to several inches from the fused fiber end of a lamp.

Yet another embodiment for delivering the light energy to the tissue includes a handpiece attached to a fiberoptic bundle, wherein the handpiece delivers the light through a focusing lens into a small cannula or hollow waveguide or sculptured sapphire tip, all of which could be used in or out of contact with the target tissue. The tips or cannulas could be detachable, autoclaveable or disposable. This embodiment could be used in contact with the tissue, or even in a procedure below the gingival tissue in the sulcus to treat periodontal disease and the like.

As can be seen from Figure 1, the apparatus of this invention is enclosed in a housing, which is preferably made of a combination of metal and injection molded plastic. The power supply 1 is internal, and may be either 110 or 220 volts. The light source 2, may be visible light such as halogen, metal halide, plasma arc or the like with an output of 12 to 500 watts. Multiple light sources are also considered to be within the scope of the present invention.

A pulse device 3 is configured to grate or optically chop the light beam emitted by the light source 2, to cause a strobe of the emitted light. The pulse device controls both pulse duration and duty cycle. Pulsing allows the treatment of tissue without anesthetic, which benefits both the doctor and the

patient. The light pulses raise the tissue temperature, and the interruptions allow the tissue to have a thermal relaxation response.

A filter 4 filters different portions of the visible spectrum of the light emitted by the light source 2. For example, the visible blue range (400-500 nm) is effective for photopolymerization, and the visible green range (480 –590 nm) is effective for surgical procedures. The filter can include a series of wavelength-specific filters that are actuated by a solenoid (not shown) to move them into the optical path. The filtering also can also be accomplished by either a filter or an optical coating on either end of the fiber optic delivery guide for each individual application. In addition, there may be multiple outlet ports, as well as multiple configurations of application-specific fiber optic guides, handpieces, and cannulas.

A control panel 5 allows an operator to control the apparatus using either a foot switch 9 or a finger control (not shown) in the handpiece 7. Remote control also is an option. The apparatus can operate as a stand-alone unit or it can be integrated into multiple operatories. The apparatus also can be integrated into traditional dental control units or into a high-tech accessory dental unit. In addition, the apparatus can be controlled by a separate foot pedal, or a foot pedal connected to a dental chair or a switch in the handpiece of the dental instrument.

The pulsed light beam generated by the apparatus of this invention is delivered to the tissue 10 through the optical fiber assembly 6, the handpiece 7, and the cannula 8.

Figure 2 shows a detailed view of the control panel 5. Control switches are provided, including a switch 21 to control the power selection, a switch 22 to control the selection of pulsing or continuous operation, and a

switch 23 to control the selection of color. The color selection switch selects the portion of the visible light spectrum that the operator desires to use, such as the wavelength range for blue light (400-500 nm) or for green light (480-590 nm), as discussed above.

5           The apparatus has multiple outlet ports 26, which allow the apparatus to be used for soft tissue surgery, photopolymerization, bleaching, illumination, caries detection, and shade matching for cosmetic dentistry. This feature allows the operator to perform two or more operations simultaneously.

10           A reflector (not shown) that is part of the light source 2 has a focal point that either is in the longitudinal axis or is off-axis to the hot spot of the bulb. The hot spot is a section of the bulb (filament or arc) in which the maximum brightness occurs. This is substantially brighter than other sections of the light source. The bulb preferably is positioned so that this hot spot is coincident with the reflector's focal point.

15           The patient contact tool (i.e., the handpiece 7 and the cannula 8) may be detached from the optical fiber assembly 6 and sterilized in an autoclave, whereas the fiber optic guide may be autoclavable or disposable.

20           A microprocessor (not shown) controls the apparatus' various operating parameters, based on inputs from the control switches, etc. In addition, the microprocessor can select pre-set operating parameters and automatic default settings for specific applications, as desired by a user.

          The microprocessor also may be coupled to one or more remote microprocessors, to allow the tool to be controlled at a site remote from the patient.

Although the invention has been described in detail with reference only to the presently preferred embodiment, those skilled in the art will appreciate that various modifications can be made without departing from the invention. Accordingly, the invention is defined only by the following claims.

What is claimed is

1. A method for performing medical and/or dental procedures on a target biological tissue, comprising:

aiming a high-intensity, polychromatic light beam onto the target biological tissue, to heat the tissue and induce a photo-thermal effect therein; and

5 pulsing the light beam for a selected duration and duty cycle, such that the tissue undergoes a thermal relaxation response between successive pulses.

2. A method as defined in claim 1, wherein aiming comprises directing the light beam through a light guide having an outlet end disposed adjacent to the target biological tissue.

3. A method as defined in claim 2, wherein pulsing includes periodically interrupting the light beam prior to its being directed through a light guide in directing.

4. A method as defined in claim 1, and further comprising:  
generating a light beam having an initial polychromatic spectrum;  
and

5 filtering the light beam to remove a portion of its initial polychromatic spectrum prior to aiming.

5. A method as defined in claim 1, wherein the method is effective as a dental procedure on hard dental tissue, including tooth bleaching, curing of dental composite materials, detecting of caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty,

5       ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination.

6.       A method as defined in claim 1, wherein the method delivers sufficient energy to the target biological tissue to raise the tissue to a temperature in the range of 37° to 175° C.

7.       A method as defined in claim 5, wherein the polychromatic light beam aimed at the target biological tissue has a power level of at least about 0.1 watt and includes wavelengths in the range of about 400 to 750 nm.

8.       A method as defined in claim 7, wherein the light beam aimed at the target biological tissue has a photo-specific energy density in the range of 10 to 5000 watts/cm<sup>2</sup>.

9.       A method as defined in claim 1, wherein:  
the method is effective as a dental procedure on soft biological tissue; and

5       the light beam aimed at the target biological tissue has a photo-specific energy density sufficient to cause hyperthermia, coagulation, welding, vaporization, carbonization, and/or rapid cutting.

10.      Apparatus for use in treating biological tissue, comprising:  
a light source for emitting a high-intensity light beam having an initial polychromatic spectrum, wherein the light source directs the light beam to an effective focal position;

5       a light guide having an inlet end disposed at the effective focal position of the light source and further having a handheld outlet end, of small

cross-section, configured to be disposed in proximity to the biological tissue to be treated.

11. Apparatus as defined in claim 10, and further comprising:  
a pulsing device for pulsing the light beam emitted by the light  
guide for a selected duration and duty cycle, such that the biological tissue being  
treated undergoes a thermal relaxation response between successive pulses; and  
5 a filter for removing a portion of the initial polychromatic spectrum  
of the light beam.

12. Apparatus as defined in claim 11, and further comprising an  
adapter selectively attachable to the outlet end of the light guide, for directing a  
portion of the light beam emitted by the light guide to the biological tissue to be  
treated.

13. Apparatus as defined in claim 12, wherein the filter is  
carried by the adapter.

14. Apparatus as defined in claim 11, wherein the pulsing  
device is configured to allow an operator to independently control both the  
duration and the duty cycle of the successive pulses of light emitted by the  
apparatus.

15. Apparatus as defined in claim 11, wherein the pulsing  
device is disposed between the light source and the light guide.

16. Apparatus as defined in claim 10, wherein the apparatus is  
configured to be suitable for use in dental procedures on hard dental tissue,  
including tooth bleaching, curing of dental composite materials, detecting of



5 caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty, ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination.

17. Apparatus as defined in claim 16, wherein the light source is selected from the group consisting of halogen lamps, metal halide lamps, and plasma arc lamps.

18. Apparatus as defined in claim 16, wherein the light source is configured to produce a light beam having a power level in the range of 12 to 500 watts.

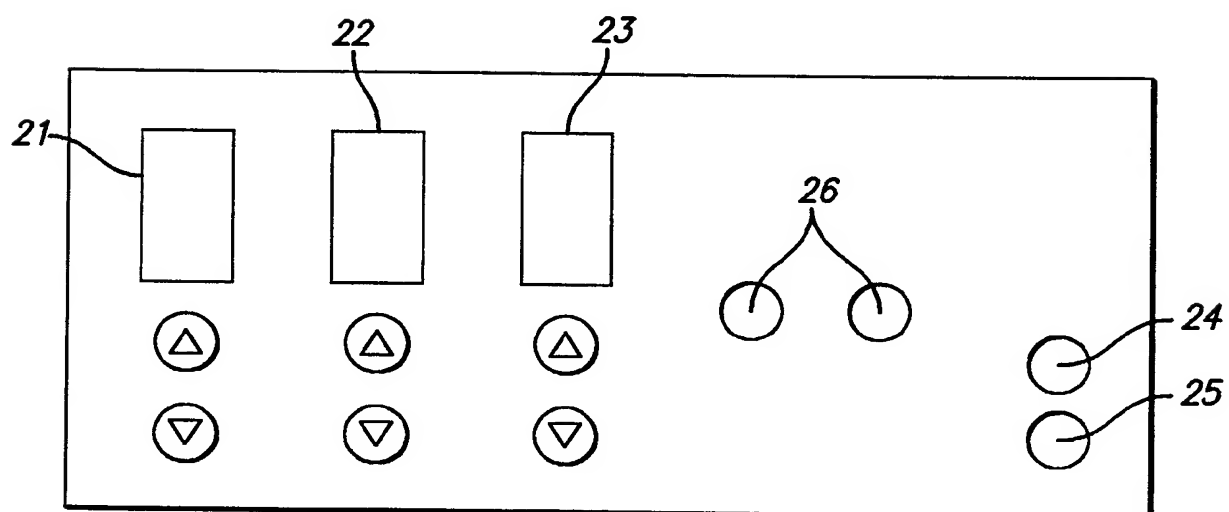
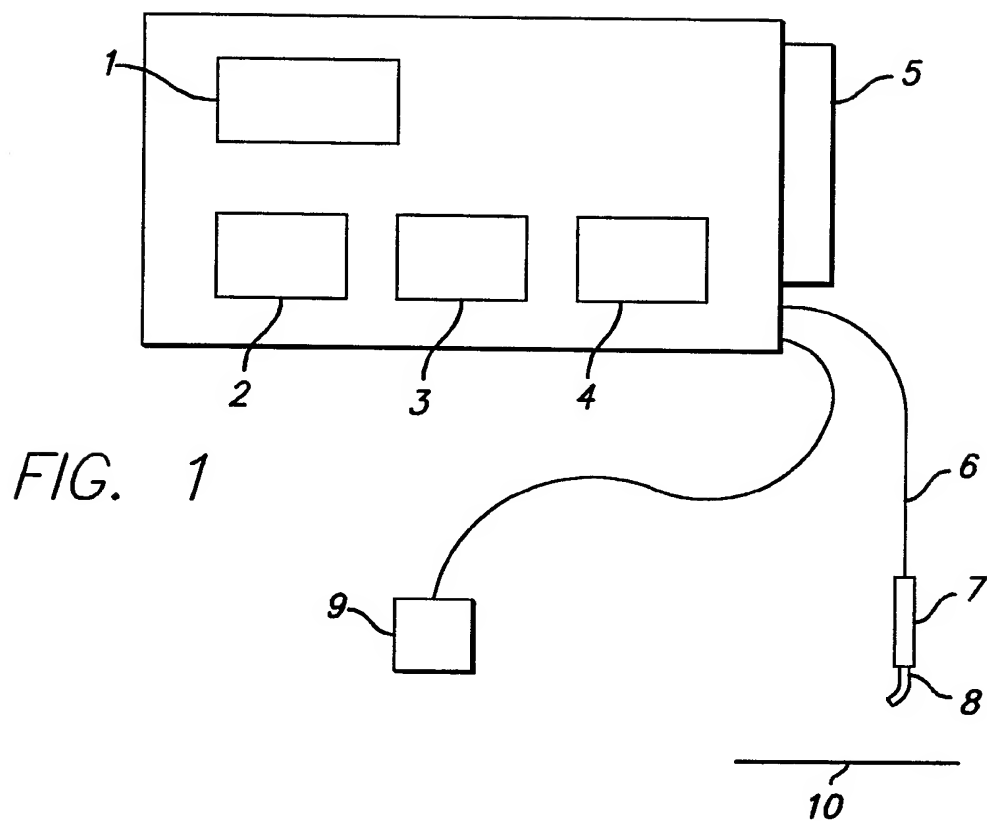
19. Apparatus as defined in claim 16, wherein the polychromatic light beam directed to the biological tissue to be treated has a power level of at least about 0.1 watt and includes wavelengths in the range of about 400 to 750 nm.

20. Apparatus as defined in claim 19, wherein the polychromatic light beam directed to the biological tissue to be treated has a photo-specific energy density in the range of 10 to 5000 watts/cm<sup>2</sup>.

21. Apparatus as defined in claim 10, wherein the light guide comprises an optical fiber assembly.

22. Apparatus as defined in claim 21, wherein:  
the optical fiber assembly includes a bundle of tightly packed optical fibers; and  
the inlet end of the optical fiber assembly has a diameter in the  
5 range of 1 to 2 mm.

1/1

*FIG. 2*

SUBSTITUTE SHEET (RULE 26)

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/02136

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 A61B18/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61B G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 860 172 A (SCHLAGER KENNETH J ET AL) 22 August 1989 (1989-08-22) column 4, line 15 - line 40; figure 1	10-21
X	WO 93 00551 A (GHAFFARI SHAHRIAR) 7 January 1993 (1993-01-07) page 15, line 8 - line 23; claims 1,5; figures 1,5	10-13, 16-21 14,15
X	US 3 327 712 A (KAUFMAN I H ET AL) 27 June 1967 (1967-06-27) column 2, line 65 - column 3, line 6 column 3, line 64 - line 68; figure 1	10,16, 17,19-22
A	US 4 852 549 A (MORI KEI) 1 August 1989 (1989-08-01) column 3, line 16 - line 19; figure 2	16

☐ Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

## \* Special categories of cited documents :

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- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

12 May 2000

Date of mailing of the international search report

19/05/2000

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# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 00/02136

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-9  
because they relate to subject matter not required to be searched by this Authority, namely:  
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

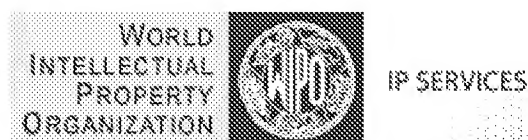
# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/US 00/02136

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Search result: 1 of 1

# (WO/2000/054649) DEVICE FOR THE THERAPEUTIC AND COSMETIC PHOTO-PROCESSING OF BIOLOGICAL TISSUES AND METHOD FOR USING THE SAME

Biblio. Data Description Claims National Phase Notices Documents

Latest bibliographic data on file with the International Bureau



Pub. No.: WO/2000/054649 International Application No.: PCT/RU2000/000088  
 Publication Date: 21.09.2000 International Filing Date: 17.03.2000

IPC: A61B 18/20 (2006.01), A61B 18/18 (2006.01)

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Priority Data: 99105549 18.03.1999 RU

Title: DEVICE FOR THE THERAPEUTIC AND COSMETIC PHOTO-PROCESSING OF BIOLOGICAL TISSUES AND METHOD FOR USING THE SAME

Abstract: The present invention relates to a method and an apparatus for permanently or temporarily removing human hair, for miniaturising the same or for changing the colour thereof. This apparatus can also be used for coagulating blood vessels, veins or a selective injury of the derma collagen in order to regenerate the same. This apparatus uses one or more incandescent lamps (4) in which the radiation spectrum (34) can be modulated in order to heat slowly and efficiently the derma (17) and in order to heat locally the hair follicles (35). This apparatus also includes an optical system that converts the blue-green portion on the spectrum of the incandescent lamps (4) into a red region of the spectrum, that provides a highly efficient concentration of converted radiation from the incandescent filament (37) of the lamps (4) on the area of biological tissues to be treated, and that ensures a repeated recirculation towards the skin (17) of the radiation scattered by the same.

Designated States: AT, AU, BR, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KR, MX, NO, NZ, PL, PT, SE, SI, US, European Patent Office (EPO) (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Publication Language: Russian (RU)

Filing Language: Russian (RU)

МЕЖДУНАРОДНАЯ ЗАЯВКА, ОПУБЛИКОВАННАЯ В СООТВЕТСТВИИ С  
ДОГОВОРом О ПАТЕНТНОЙ КООПЕРАЦИИ (PCT)

<b>(51) Международная классификация изобретения <sup>7</sup>:</b> <b>A61B</b>	<b>A2</b>	<b>(11) Номер международной публикации:</b> <b>WO 00/54649</b> <b>(43) Дата международной публикации:</b> 21 сентября 2000 (21.09.00)
<b>(21) Номер международной заявки:</b> PCT/RU00/00088 <b>(22) Дата международной подачи:</b> 17 марта 2000 (17.03.00) <b>(30) Данные о приоритете:</b> 99105549 18 марта 1999 (18.03.99) RU <b>(71) Заявитель (для всех указанных государств, кроме (US):</b> ЗАКРЫТОЕ АКЦИОНЕРНОЕ ОБЩЕСТВО «LS» [RU/RU]; 193036 Санкт-Петербург, ул. Восстания, д. 15 (RU) [ZAKRYTOE AKTSIONERNOE OBSHCHE- STVO «LS», St.Petersburg (RU)]. <b>(72) Изобретатели; и</b> <b>(75) Изобретатели/Заявители (только для (US):</b> АКОПОВ Леонид Иванович [RU/RU]; 197198 Санкт-Петербург, ул. Колпинская, д. 7, кв. 6 (RU) [AKOPOV, Leonid Ivanovich, St.Petersburg (RU)]. БЕЛИКОВ Андрей Вячеславович [RU/RU]; 198217 Санкт-Петербург, пр. Народного Ополчения, д. 141, кв. 86 (RU) [BELIKOV, Andrei Vyacheslavovich, St.Petersburg (RU)]. БИРЮ- ЧИНСКИЙ Сергей Борисович [RU/RU]; 196135 Санкт-Петербург, Московский пр., д. 200, корп. 4, кв. 94 (RU) [BIRJUCHINSKY, Sergei Borisovich, St.Peters- burg (RU)]. ИНОЧКИН Михаил Владимирович [RU/ RU]; 197198 Санкт-Петербург, Кронверкский пр., д. 73, кв. 29 (RU) [INOCKIN, Mikail Vladimirovich, St.Petersburg (RU)].		<b>(74) Общий представитель:</b> АКОПОВ Леонид Иванович; 190000 Санкт-Петербург, ул. Колпинская, д.7, кв. 6 (RU) [AKOPOV, Leonid Ivanovich, St.Petersburg (RU)]. <b>(81) Указанные государства:</b> AT, AU, BR, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KR, MX, NO, NZ, PL, PT, SE, SI, US, европейский патент (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). <b>Опубликована</b> <i>Без отчёта о международном поиске и с повторной          публикацией по получении отчёта.</i>
<b>(54) Title:</b> DEVICE FOR THE THERAPEUTIC AND COSMETIC PHOTO-PROCESSING OF BIOLOGICAL TISSUES AND METHOD FOR USING THE SAME <b>(54) Название изобретения:</b> УСТРОЙСТВО ДЛЯ ТЕРАПЕВТИЧЕСКОЙ И КОСМЕТОЛОГИЧЕСКОЙ ФОТООБРАБОТКИ БИОТКАНИ И СПОСОБ ЕГО ИСПОЛЬЗОВАНИЯ <b>(57) Abstract</b> <p>The present invention relates to a method and an apparatus for permanently or temporarily removing human hair, for miniaturising the same or for changing the colour thereof. This apparatus can also be used for coagulating blood vessels, veins or a selective injury of the derma collagen in order to regenerate the same. This apparatus uses one or more incandescent lamps (4) in which the radiation spectrum (34) can be modulated in order to heat slowly and efficiently the derma (17) and in order to heat locally the hair follicles (35). This apparatus also includes an optical system that converts the blue-green portion on the spectrum of the incandescent lamps (4) into a red region of the spectrum, that provides a highly efficient concentration of converted radiation from the incandescent filament (37) of the lamps (4) on the area of biological tissues to be treated, and that ensures a repeated recirculation towards the skin (17) of the radiation scattered by the same.</p>		

Предлагается прибор и процесс для постоянного и временного удаления человеческих волос, их миниатюризации и изменения цвета. Прибор может использоваться также для коагуляции кровяных сосудов, вен и селективного повреждения коллагена дермиса с целью его регенерации. В приборе используется одна или несколько ламп накаливания (4) с модуляцией спектра излучения (34), обеспечивающего эффективный мягкий нагрев дермиса (17) и локальный нагрев волосяной фолликулы (35). Прибор содержит оптическую систему обеспечивающую преобразование сине-зеленой части спектра лампы накаливания (4) в красную область спектра, а также высокоэффективную концентрацию преобразованного излучения нити накала (37) ламп (4) на обрабатываемую область биоткани (17) и многократную циркуляцию излучения рассеянного от кожи (17) обратно в кожу (17).

### ИСКЛЮЧИТЕЛЬНО ДЛЯ ЦЕЛЕЙ ИНФОРМАЦИИ

Коды, используемые для обозначения стран-членов РСТ на титульных листах брошюр, в которых публикуются международные заявки в соответствии с РСТ.

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				ZW	Зимбабве



## **Устройство для терапевтической и косметологической фотообработки биотканей и способ его использования**

### **Область техники**

- Изобретение относится к медицинской технике и может применяться в дерматологии для постоянного и временного удаления человеческих волос, их миниатюризации и изменения цвета, а также для коагуляции кровеносных сосудов и селективного повреждения коллагена и подкожного жира.

### **Предшествующий уровень техники**

- Известны устройства фотообработки биотканей, работа которых основана на селективном нагреве желаемой области биоткани (кожи, кровеносного сосуда или волосяной фолликулы). В качестве источника излучения в этих устройствах используются лазеры или дуговые лампы.

- В основном для селективного нагрева используются лазерные источники света. Это связано с тем, что лазер обеспечивает наилучшую спектральную селективность. Кроме того лазер, позволяет получить любую длительность импульса вплоть до нескольких фемтосекунд, и тем самым, обеспечить селективный нагрев биологических структур любых размеров. Излучение лазера легко фокусируется в малый объем. Это позволяет достичь желаемого уровня плотности энергии, а также обеспечить высокую эффективность ввода излучения в оптическое волокно и доставку его к операционному полю. В то же время лазер является самым дорогостоящим источником света и обладает повышенной опасностью прежде всего для зрения пользователя.

- Для ряда применений возможности селективного лазерного нагрева не являются необходимыми и могут быть осуществлены некогерентными источниками, например, лампой. При этом, для спектральной селекции используется поглощающий или флуоресцентный фильтр. В патенте США №3,327,712 предложено использовать дуговую лампу, с фильтром в области 300-600нм и доставкой излучения по жгуту волокон, для коагуляции тканей, а в патенте США №4,298,005 - устройство содержащее дуговую лампу, отражатель и спектральный фильтр в диапазоне 320-450 нм для косметологических применений. Это устройство не требует волоконной доставки излучения.

- В патенте США №5,320,618 описано устройство, в котором для селекции излучения дуговой лампы используется флуоресцентный фильтр. Флуоресцентный фильтр поглощает энергию коротковолновой части спектра лампы, которая не воздействует на мишень и переизлучает ее в длинноволновую область, для которой поглощение мишени имеет значительную величину. В патенте США №3,693,623 впервые предложено использовать дуговую лампу с зеленым фильтром и доставкой излучения по оптическому волокну для удаления единичного волоса путем коагуляции кровеносных сосудов в папилле.

Общий недостаток приведенных выше патентов состоит в том, что описанные в них устройства содержат дуговую лампу,

которая вообще говоря, дешевле и проще лазера, однако требует высоковольтных сильноточных источников питания и не может эксплуатироваться в домашних условиях или в косметических салонах. Кроме того, прибор на основе дуговой лампы имеет  
5 весьма низкую эффективность. Это связано с тем, что эффективность преобразования электрической энергии в них в свет не превышает 60%, а плотность мощности на внешней поверхности плазменного столба из-за малого коэффициента "черноты" имеет  
10 небольшую величину, что ограничивает максимальный поток, падающий на поверхность кожи.

Для создания максимально дешевых фотоэпиляторов и фотокосметических приборов в настоящее время наиболее подходящим источником света является лампа накаливания. Лампа накаливания может питаться безопасными для человека  
15 источниками с низким напряжением, а эффективность преобразования электрической энергии в световую у лампы накаливания выше, чем у дуговых ламп (0,85 и 0,6 соответственно). Спектральная эффективность лампы накаливания для синего и зеленого диапазона ниже чем у дуговой из-за ограниченной  
20 температуры нити ( $< 3800^{\circ}\text{K}$ ), однако в диапазоне длин волн, в котором наиболее эффективно повреждается волос (больше 600нм) спектральная эффективность не уступает эффективности дуговых ламп с той же цветовой температурой. Плотность энергии на поверхности нити накала выше чем на поверхности плазменного  
25 столба, что позволяет достичь большей плотности энергии на поверхности кожи. Лампа накаливания в отличие от дуговой лампы не может эффективно излучать импульсы короче 50мс, что обычно необходимо для селективного нагрева области волосяного столба или папиллы в особенности для тонких волос или тонкого слоя  
30 дермиса, подкожного жира или кровеносных сосудов. Поэтому для создания дешевого и безопасного прибора для удаления волос на основе лампы накаливания необходимо обеспечить дополнительные приемы повышения эффективности воздействия, что и является предметом настоящего изобретения.

35 Наиболее близким к предлагаемому устройству и выбранным в качестве прототипа является устройство для коагуляции кровеносных сосудов ( Пат. США №4.539.987 опубликован 10.09.1985г.).

40 Это устройство содержит источник электромагнитного излучения в виде лампы накаливания, рефлектор для концентрации излучения на обрабатываемую область биоткани, при этом между лампой накаливания и обрабатываемой биотканью помещен кристаллический диэлектрик прозрачный для излучения и находящийся в контакте с обрабатываемой биотканью. Этот  
45 кристаллический элемент, соединенный с системой охлаждения или теплоемкой массой, предназначен для отвода тепла от приповерхностного слоя кожи. Между лампой и прозрачным диэлектриком может быть помещен поглощающий фильтр, пропускающий излучение в области 600-1400нм. В устройстве

используется лампа накаливания с электрической мощностью более 15Вт, с плотностью мощности на поверхности обрабатываемой биоткани более 10Вт/см<sup>2</sup>. Рекомендуемая в этом патенте плотность мощности составляет 150Вт/см<sup>2</sup>, для чего  
5 предполагается в устройстве использовать лампу накаливания с максимальной электрической мощностью порядка 400 Вт, которая работает в обычном непрерывном режиме с временем воздействия около 2 сек. Коагуляция кровеносных сосудов осуществляется главным образом за счет поглощения излучения лампы водой,  
10 содержащейся в коже.

Недостатком этого устройства является непригодность для эффективного локального нагрева волоса или мелкого кровеносного сосуда, тонкого слоя дермиса или подкожного жира. Действительно, как показано в патенте США №5735844 опубл.  
15 07.04.1998г., для поражения волоса необходимо излучение с длиной волны от 600÷1100нм, с плотностью энергии не менее 10Дж/см<sup>2</sup> при длительности импульса 1-20 мс. Таким образом плотность мощности в этом диапазоне должна быть не менее 500Вт/см<sup>2</sup>, что значительно выше, чем может быть получено с  
20 использованием лампы накаливания с максимальной электрической мощностью 400Вт в непрерывном режиме, при диаметре освещенной зоны на поверхности биоткани 25 мм. Заметим, что номинальная мощность 400Вт является практическим пределом для миниатюрных галогенных ламп, излучение которых может быть  
25 сконцентрировано на небольшой (Ø10-25 мм) площадке. При этих условиях световая мощность в области спектра 600-1400нм на поверхности биоткани не будет превышать 150 Вт (полная световая эффективность 0.8, эффективность осветителя 0.8, доля светового излучения в области 600-1400 нм - 0.6: 0.8·0.8·0.6=0.4), а  
30 плотность мощности - 40Вт/см<sup>2</sup>, что опять таки значительно ниже необходимых 500Вт/см<sup>2</sup>. Обратным расчетом легко убедиться, что необходимая мощность лампы должна составлять более 6кВт.

Наиболее близким к предлагаемому способу использования заявляемого устройства, и принятым в качестве прототипа,  
35 является способ удаления волос, описанный в вышеупомянутом патенте (см. Патент США №5735844 опубл. 07.04.1998г.). В этом способе используются короткие световые импульсы длительностью от 2 до 100 мс с частотой следования 1 Гц и длиной волны в диапазоне от 680 до 1200нм в сочетании с охлаждением  
40 эпидермиса. Сущность прототипа состоит в том, что в указанном диапазоне длин волн меланин, содержащийся преимущественно в матриксе клеток волосаной фолликулы и стволе волоса, обладает более высоким поглощением чем все остальные компоненты кожи. Поэтому возможен селективный нагрев волосаной фолликулы и  
45 поражение ее органов ответственных за рост волоса: матрикса клеток в области папиллы и стим-клеток в области ствола волоса. Так как меланин содержится также на границе дермиса и эпидермиса, то при поражении фолликулы возможно одновременное поражение эпидермиса, например его отслоение.

Для предотвращения поражения эпидермиса в этом способе используется предварительное и одновременное со световым воздействием охлаждение эпидермиса. Способ удаления волос, описанный в этом патенте, предназначен для одновременной обработки одним световым импульсом нескольких волосяных фолликул. Плотность энергии оптических импульсов лежит в пределах от 10 до 200 Дж/см<sup>2</sup>, и предполагается использование любых импульсных источников электромагнитного излучения, включая лазеры и некогерентные источники, с указанными выше параметрами.

Недостатком прототипа способа является недостаточная эффективность использования электромагнитной энергии при обработке из-за неоптимального режима воздействия на биоткань оптических импульсов с высокой плотностью энергии.

Раскрытие изобретения

Задачей, на решение которой направлено предлагаемое изобретение, является удешевление устройства с одновременным повышением эффективности и безопасности поражения волосяной фолликулы для перманентного ее повреждения или задержки роста, миниатюризации или осветления волоса, а также коагуляции кровеносных сосудов и селективного повреждения коллагена кожи или подкожного жира.

Данная задача решается за счет достижения технического результата, заключающегося в оптимальном использовании свойств обрабатываемой биоткани, заключающемся в изменении ее состояния в зависимости от времени, энергии и спектра воздействующего излучения.

Для достижения указанного технического результата лампа накаливания, которая является источником электромагнитного излучения в предлагаемом устройстве соединена с блоком питания через модулятор. Этот модулятор содержит измеритель сопротивления нити накала лампы и регулятор мощности, что позволяет обеспечить оптимальный режим обработки биотканей. Внутренняя поверхность рефлектора, предназначенного для концентрации излучения лампы на биоткань, выполнена зеркальной с функцией возврата излучения, отраженного от обрабатываемой биоткани, обратно в биоткань. Это позволяет значительно повысить эффективность функционирования устройства.

В контакте с обрабатываемой тканью при работе устройства находится охлаждаемая диэлектрическая призма, представляющая собой волновод. С целью обеспечения дополнительной безопасности обработки к этой диэлектрической призме вплотную присоединена металлическая пластина, которая также находится в контакте с обрабатываемой тканью и соединена с системой охлаждения. При этом при обработке ткани устройство перемещается так, что необлученный участок кожи сначала соприкасается с металлической пластиной, а затем с диэлектриком.

В устройстве предусмотрен также спектральный фильтр, поглощающий вредное для биоткани излучение, который с

диэлектрическим элементом образует оптический волновод. Это, в сочетании со сферической внутренней поверхностью рефлектора и конической боковой его поверхностью обеспечивает возврат излучения, отраженного от биоткани, обратно в биоткань.

5 Дополнительно, внутренне пространство рефлектора может быть снабжено системой воздушного охлаждения.

Кроме отдельного спектрального фильтра баллон лампы накаливания, зеркальное покрытие внутренней поверхности рефлектора, могут быть выполнены с функцией люминесцентного

10 спектрального преобразователя.

Бытовой вариант предлагаемого устройства для, например, удаления волос в домашних условиях может быть выполнен в виде "щипцов", захватывающих фрагмент кожи с волосяной фолликулой с учетом концентрации излучения на них в сомкнутом состоянии

15 щипцов. Профессиональный вариант предлагаемого устройства может быть выполнен с использованием нескольких миниатюрных ламп с напряжением питания ниже 40В. Бытовой вариант предлагаемого устройства может содержать одну миниатюрную лампу с напряжением питания до 40В.

20 Способы использования предлагаемого устройства для обработки различных биотканей отличаются временем воздействия, спектральным диапазоном и временем облучения. Причем предварительно происходит охлаждение обрабатываемой поверхности, а затем облучение в две фазы. Исключением является

25 случай повреждения коллагена дермиса с целью стимуляции его регенерации или повреждения слоя подкожного жира.

В предлагаемом устройстве используются лампы накаливания и модулятор тока или напряжения, который изменяет спектр излучения

30 лампы во времени так, что вначале воздействия света на кожу (первая фаза - преднагрев) максимум излучения сосредоточен в ближнем ИК диапазоне, а в конце воздействия он смещается в красную область спектра ( вторая фаза - поражение). На первой фазе происходит нагрев дермиса за счет поглощения излучения

35 водой, содержащейся в дермисе, до температуры не превышающей температуру его денатурации 45-55°C. На второй фазе, при смещении максимума спектра излучения в красную область спектра, происходит селективный нагрев компонент волоса содержащих меланин: матрикса клеток и ствола волоса и находящихся рядом с ними папиллы и стим-клеток. Т.к. на 1 фазе их начальная температура становится на 9°-15°C выше обычной для

40 кожи, то для селективного нагрева и поражения на 2 фазе требуется на 30-40% меньшая энергия, чем при нагреве без 1 фазы. Для предохранения эпидермиса от поражения используется

45 контактное охлаждение, температура эпидермиса может измеряться и при достижении температуры кожи в течение 1 фазы заданного уровня, нагрев может быть остановлен, а энергия излучения на второй фазе устанавливается на безопасном уровне.

Отличительная особенность второй фазы состоит в том, что мощность лампы на этой фазе значительно превышает номинальную, но в силу наличия преднагрева лампы на первой фазе и малой длительности второй фазы это не приводит к  
5 разрушению нити накала лампы.

Излучение лампы или нескольких ламп накаливания, как и в прототипе, с помощью рефлектора направляется на обрабатываемый участок кожи. В отличие от прототипа этот рефлектор в сочетании с волноводом построен так, что он  
10 возвращает излучение, отраженное от биоткани, обратно в биоткань. Тем самым повышается эффективность использования мощности лампы. Дополнительно, эффективность устройства повышается за счет использования люминесцентного преобразователя энергии, ультрафиолетового, синего и зеленого  
15 излучения в желто-красную область спектра.

Краткое описание фигур чертежей

Сущность изобретения поясняется фигурами, где на фиг.1 показана блок-схема устройства и сечение его наконечника. Фиг.2 показывает временные диаграммы мощности лампы, длины  
20 волны максимума излучения, долей излучения лампы в инфракрасной и красной областях спектра, а также сопротивления лампы.

На фиг. 3 показано распределение температуры внутри кожи по окончании первой фазы - преднагрева, а

25 фиг. 4 иллюстрирует зависимости температуры базального слоя, стим-клеток и матрикса клеток волосяной фолликулы от времени на второй фазе.

Фиг. 5 показывает сечения наконечников упрощенного варианта устройства малой средней мощности и выполненных в виде  
30 "щипцов". Фиг. 6 показывает сечение лампы устройства содержащей несколько "плоских" спиралей.

На фиг. 7 показано сечения наконечника содержащего четыре лампы.

Описанные ниже схемы и режимы работы предлагаемого  
35 устройства не исчерпывают всех возможных вариантов реализации данного изобретения. Устройство может широко использоваться для термического воздействия на различные компоненты кожи с использованием лампы накаливания. Применение этого устройства не ограничивается фотоэпиляцией или фотомодификацией волос,  
40 может использоваться для воздействия на крупные кровеносные сосуды, ножные вены с целью их лечения, на collagen дермиса с целью его регенерации, фотобиостимуляции и др.

Лучший вариант осуществления изобретения

Устройство состоит (фиг. 1) из наконечника 1, гибкого жгута  
45 2 проводов и трубопроводов и блока питания и управления 3. Наконечник 1 состоит из галогенной лампы накаливания 4, которая помещена в трубку 5 из стекла или диэлектрического кристалла, рефлектора 6, выполненного из металла или оптического материала, на внутреннюю поверхность которого нанесено

высокоотражающее покрытие 7, фильтра-волновода 8, представляющего из себя сэндвич-структуру: люминесцентный преобразователь 9 - охлаждающая незамерзающая жидкость 10 - оптический теплоизолятор 11, призмы 12 из

5 высокотеплопроводного прозрачного диэлектрического материала и закрепленной в металлической оправе 13, которая через термоэлектрические элементы 14 (например, элементы Пельтье) подсоединена к охлаждаемым водой или воздухом терморadiаторам 15. Сэндвич-структура фильтра 8 образует с

10 диэлектрической призмой 12 оптический волновод. Оправа 13 с одной стороны имеет продолжение в виде металлической пластины 16, соединенной с термоэлектрическим элементом 14. Нижняя поверхность пластины 16 и призмы 12 находятся в контакте с обрабатываемой биотканью 17. К призме 12 приставлен

15 термосенсор 18, представляющий собой термopару, термистор или радиометр. Указанные детали смонтированы в теплоизолирующем корпусе 19. Наконечник 1 соединен с блоком питания и управления 3 с помощью жгута 2 электрических проводов 20 для питания лампы 4 и проводов 21 для питания термоэлектрических элементов

20 14. Жидкостные шланги 22 служат для подачи охлаждающей жидкости, которая должна циркулировать через отверстия 23 в рефлекторе 6 и терморadiаторе 15. Воздухопровод 24 служит для подачи и прохождения сжатого воздуха через канал 25 в корпус 19 и рефлектор 6, далее через отверстия 26 в трубке 5, рефлекторе 6,

25 корпусе 19 и в узлах крепления электродов 27. Провода 28 служат для подачи сигнала с термосенсора 18. Блок питания и управления 3 состоит из блока питания - 29, модулятора тока, напряжения или мощности - 30, компрессора 31, микропроцессора 32, и системы охлаждения с жидкостным насосом 33.

30 Устройство, на примере удаления волос, работает следующим образом: излучение 34 лампы 4 прямо или с помощью рефлектора 6 через блокирующий нежелательный спектр элемент 8 попадает на кожу 17 и воздействует на нее посредством поглощения водой. Это излучение воздействует также на цель -

35 например, на волосяную фолликулу 35 через поглощение света меланином или кровеносный сосуд через поглощение света элементами крови. Известно, что в следствии объемного рассеяния в коже значительная часть излучения рассеивается назад (S. R. Utz and et. Percutaneous blood laser biostimulation. First clinical results. Pros. SPIE, vol.1643, p. p. 228-239, 1992). Этот эффект максимален в красной области спектра, там где поглощение кожи минимально. Коэффициент отражения может достигать 80% процентов (Peters V.G. at all. Phys. Med. Biol.35, 1990, p.p. 1317-1334). Если, например, часть рефлектора 6, расположенная над лампой

40 накаливания 4, представляет собой часть сферы, а центр кривизны этой сферы расположен на ближайшей к лампе 4 грани 36 фильтра 8, то диффузно отраженное от кожи 17 излучение 34, пройдя волновод, образованный элементами 8 и 12, выходит через эту грань. Затем, попав на сферическую зеркальную поверхность 7

рефлектора 6, возвращается снова на указанную грань 36 и далее через волновод снова на кожу 17. В предлагаемом устройстве это излучение направляется назад на отражающее покрытие 7 рефлектора 6 и снова возвращается в кожу 17. Причем, тупой угол наклона боковой внутренней поверхности 7 рефлектора 6 обеспечивает попадание на сферическую часть даже лучей, которые выйдя из грани 36 попали на боковую поверхность.

Эффективность обратного отражения очень высока т.к. внутренняя поверхность 7 рефлектора 6 покрыта высокоотражающим материалом: Cu, Au или Ag или многослойным диэлектрическим покрытием. Коэффициент отражения превышает 90%. Кроме того площадь поверхности нити накала 37 лампы накаливания 4 очень мала, материал трубки 5 и рефлектора 6 обладает очень малым поглощением на длинах волн света, воздействующего на кожу 17. Поэтому, на каждое переотражение излучения в кожу 17 возвращается  $Rr^n$  часть падающей на нее энергии, где R - коэффициент отражения кожи, r - коэффициент отражения поверхности 7 рефлектора 6, n - число отражений. В результате многократных отражений освещенность внутри кожи увеличится в  $\frac{1}{1-Rr^n}$ . При R=0,8, r=0,90 и n=2 эффект усиления

освещенности достигает четырех раз. Следует отметить, что наилучший эффект усиления освещенности внутри кожи за счет рециркуляции фотонов обеспечивается при размере пятна более 10 мм.

Рассмотрим режим нагрева лампы с использованием блока питания 29 и модулятора 30. Для поражения волосяной фолликулы 35 наиболее благоприятная область спектра лампы 600-1100нм. В этой области меланин имеет достаточно высокое поглощение и в тоже время рассеяние составляет умеренную величину, так что свет может проникать в кожу на достаточную глубину. Галогенные лампы имеют пиковую температуру 3000°K - 3600°K. При 3000°K 5% излучения сосредоточено в области длин волн  $\lambda < 600\text{нм}$ , 34% в области  $600\text{нм} < \lambda < 1100\text{нм}$ , и 48%  $1100\text{нм} < \lambda < 2500\text{нм}$ . При 3500°K эти проценты перераспределяются так 10%  $\lambda < 600\text{нм}$ , 42%  $600\text{нм} < \lambda < 1100\text{нм}$ , 35%  $1100\text{нм} < \lambda < 2500\text{нм}$ . Таким образом, для максимальной эффективности преобразования электрической энергии в полезную световую энергию выгодно форсировать мощность и температуру галогенной лампы 4. Однако, при этом резко уменьшается срок службы лампы, если она работает в обычном непрерывном режиме. В предлагаемом изобретении используется электрический модулятор 30, с помощью которого на лампу 4 подается короткий мощный импульс тока или напряжения, вызывающего превышение рассеиваемой лампой мощности над номинальной. Исследования, проведенные авторами с лампой OSRAM тип ELC (Германия), имеющей номинальную мощность  $P_n=250\text{Вт}$ , показали, что температуре 2800°K соответствует мощность 150Вт, при токе 9А и напряжении 17В. Если ток повысить



- до 12,5А на промежуток времени 0,2 с, то в лампе будет рассеиваться мощность 360Вт, что в 1.45 раза больше номинальной (фиг. 2а). При этом температура достигает 3600°K, т.е. приближается к максимальной. В режиме, когда средняя
- 5 температура нити порядка 2800°K, а на короткое время (0,2с) достигается максимальная температура 3600°K, лампа 4 может функционировать очень продолжительное время без деградации или разрушения. Временной диаграмме мощности лампы отвечает временная диаграмма светового излучения приведенная на фиг.
- 10 2б. Форма светового импульса может отличаться от формы электрического в силу тепловой инерции нити накала 37. Тепловая инерция зависит от диаметра нити накала 37. При практическом пределе диаметра нити 37 0,2мм, время тепловой инерции составляет 0,04с, а минимальная длительность светового импульса
- 15  $t_2$  на полувысоте может достигать 0,1с. Для лампы мощностью 250Вт в таком импульсе может быть сосредоточено до 50Дж световой энергии при длительности 0,2с по полувысоте. Путем регулирования тока лампы 4 модулятором 30 также осуществляется перестройка спектра излучения лампы 4. На первой фазе
- 20 длительностью  $t_1$  ток лампы ниже номинального, температура нити 37 2800°K и максимум излучения лежит в ИК области спектра (1030нм). На второй фазе температура нити 37 достигает 3600°K и максимум излучения перестраивается в красную (800нм) область (фиг. 2 с). Соответственно изменяется доля излучения лежащая в
- 25 области 1100-2500нм-  $P_{ИК}$  и 600÷1100нм -  $P_K$  (рис. 2д). Дополнительно, для автоматической защиты лампы 4 от разрушений в модуляторе 30 производится непрерывное измерение сопротивления лампы. При подаче импульса тока выше чем номинальный, сопротивление нити накала 37 увеличивается, и
- 30 в момент  $t_m$  (фиг. 2д), когда сопротивление достигает критической величины, модулятор 30 автоматически ограничивает рассеиваемую мощность. С этой целью модулятор 30 содержит измеритель сопротивления 38 нити накала 37 лампы 4, связанный с регулятором тока, напряжения или мощности.
- 35 Способ обработки различных биотканей с помощью предлагаемого устройства определен исходя из степени восприимчивости той или иной биоткани к параметрам облучения. В частности для удаления волос способ использования устройства определен по свойствам кожи и волосяной луковицы(см. например,
- 40 A. Waldman et all Laser hair removal: theory and clinical experience Proc. of SPIE 1998 vol. 3245 p.p. 318-321).
- Расчеты, проведенные по разработанной авторами математической модели, показали, что необходимы две фазы нагрева: длительный (преднагрев) и кратковременный (нагрев и
- 45 разрушение). Кроме того, для фотодеструкции волосяной фолликулы необходимо сначала охладить верхний слой кожи (эпидермис) затем, продолжая охлаждать начинать облучать кожу.

Действительно, в области спектра 1100÷2500нм кожа обладает сильным поглощением (поглощение воды) и слабым рассеянием. На отдельных участках спектра излучение может глубоко проникать в кожу. В диапазоне 600-1100нм преимущественным поглощением обладает меланин и гемоглобин крови. Таким образом, на первой фазе воздействия излучения на кожу осуществляется ее неселективный нагрев за счет поглощения излучения водой. На второй фазе осуществляется селективный нагрев структур кожи содержащих меланин (эпидермис, ствол волоса, матрикс клеток волосяной луковицы) и гемоглобин (кровеносные сосуды, вены). Роль первой фазы состоит в преднагреве поражаемой цели (волосяная луковица, кровеносный сосуд) с 30-36°C до 45-55°C, (что ниже температуры денатурации белка). Это производится с целью уменьшения уровня энергии необходимой для нагрева на второй фазе. На второй фазе коротким импульсом осуществляется нагрев поражаемой цели (волосяная луковица, сосуд) до температуры денатурации белка 65-75°C.

Обычно максимум освещенности находится на поверхности или в приповерхностном слое кожи. Это не позволяет осуществить равномерный нагрев глубинных слоев кожи. Наличие контактного охладителя 16 с отрицательной температурой, поддерживаемой холодильником в виде термоэлектрических элементов 14 или терморadiatorом 15 с циркулирующей водой, позволяет снизить температуру поверхности и приповерхностного слоя, а также сместить максимум температуры на первой фазе в глубь кожи. Комбинируя температуру охладителя и мощность лампы можно плавно управлять профилем температуры внутри кожи. Этот эффект можно использовать для селективного поражения коллагена с целью стимуляции его роста.

На Фиг. 3 показан типичный профиль температуры внутри кожи, рассчитанный для случая контактного охладителя из кристалла сапфира с температурой -10°C и лампы с номинальной мощностью 250Вт и температурой нити 3600°K через освещаемый участок кожи 1.5x1.5 см<sup>2</sup> и через 1 сек после начала воздействия (первая фаза). К моменту окончания этой фазы за счет использования контактного охладителя 16 температура базальной мембраны понижена до 17°C. Это позволяет защитить эпидермис от поражения на второй фазе.

На фиг. 4 показаны временные диаграммы температуры (вторая фаза) базальной мембраны (кривая 1), стим-клеток (кривая 2) и матрикса клеток волосяной фолликулы (кривая 3). Горизонтальная прямая (4) соответствует температуре денатурации белка. Максимальная температура лампы накаливания 3600°K, пиковая мощность в 1.45 раз больше номинальной, пиковая плотность мощности излучения в диапазоне спектра 600÷1100нм 81,6Вт/см<sup>2</sup>, размер пятна 1.5x1.5 см<sup>2</sup>, длительность второй фазы 0,2сек. Для достижения эффекта термического поражения волосяной луковицы 35 необходимо чтобы температура в области

папиллы, стим-клеток достигала температуры денатурации белка т.е. 65-75°C. Расчеты, проведенные на основе моделей кожи и волосяной луковицы с использованием данных описанных в литературе (M. H. Niemz "Laser-Tissue Interaction, Fundamentals and Application", Springer, 1995) показывают, что для конструкции прибора, описанного выше, оптимальный способ фотодеструкции волосяной фолликулы состоит в следующем: кожу предварительно охлаждают за счет контакта с металлической пластиной 16 и диэлектрической призмой 12, затем, сохраняя контакт и продолжая  
5 охлаждать, нагревают дермис излучением в диапазоне 1100-2500 нм с максимумом 1300-1400 нм и плотностью 10-60 Вт/см<sup>2</sup> и с длительностью 0,1-100 сек. На второй фазе, непосредственно следующей за первой, проводится деструкция в волосяной фолликулы излучением длительности 0,05-10 сек в диапазоне 600-  
10 1200 нм с максимумом в области 600-1000 нм и плотностью мощности 80-800 Вт/см<sup>2</sup>.

Способ использования устройства для коагуляции кровеносных сосудов определен в основном из оптических свойств гемоглобина(см. например T.G.Pfefer et al Laser treatment of port  
20 wine stains: three dimensional simulation using a biopsy-defined geometry in an optical-thermal model Proc. of SPIE 1998 vol. 3245 p.p. 322-333). Также как и в случае волосяной фолликулы необходимо предварительное охлаждение, затем, одновременно с охлаждением облучение в две фазы. Расчеты показывают, что на первой фазе  
25 длительностью 0,1-100 сек облучение производится излучением в диапазоне 500-2500 нм с максимумом в области 700-1500 нм и плотностью мощности 1-50 Вт/см<sup>2</sup>. На второй фазе для коагуляции сосудов или вен длительность воздействия должна быть 0,05-5 сек в диапазоне 400-1200 нм с максимумом в области 500-1100 нм и  
30 плотностью мощности 10-500 Вт/см<sup>2</sup>.

Описанное устройство может применяться также для селективного повреждения коллагена дермиса с целью стимуляции его роста и как следствие, улучшения косметических свойств кожи - снижение морщинистости, повышение эластичности или для  
35 поражения подкожного жира. Как показали расчеты на основе нашей модели с использованием литературных данных (A. Welch, Optical-Thermal response of laser-irradiated tissue, Plenum Press, NY.,1996), оптимальным режимом для селективного поражения коллагена с помощью описанного устройства является следующий:  
40 кожу охлаждают за счет контакта с металлической пластиной 16 и диэлектрической призмой 12 и облучают светом ламп накаливания в диапазоне 600-2500 нм с длительностью 0,1-1000 сек с плотностью мощности от 0.1 до 500 Вт/см<sup>2</sup>. При этих режимах, за счет одновременного охлаждения поверхности и объемного  
45 нагрева дермиса или подкожного жира излучением лампы накаливания, максимум температуры смещается в глубь кожи, и поражение слоя коллагена происходит внутри дермиса при сохранении эпидермиса. Глубина поражения определяется длительностью нагрева и охлаждения. Чем ниже мощность и

дольше охлаждение, тем глубже лежит область поражения. Охлаждение кожи при использовании описанного устройства может происходить при скольжении вдоль поверхности с сохранением теплового контакта. В этом случае новый необлученный участок  
5 кожи сначала соприкасается с металлической пластиной 16 и предварительно охлаждается, а затем этот участок соприкасается с призмой 12 и охлаждается одновременно с облучением.

Изображенные на фиг. 5 упрощенные (в виде щипцов) варианты наконечника предлагаемого устройства отличаются тем,  
10 что в них прозрачный диэлектрик 12 выполнен составным (разделенным на две половины вдоль плоскости симметрии 39) из материала, поглощающего вредное для обрабатываемой биоткани излучение лампы 4, т.е. в нем совмещены функции фильтра 8. При этом, каждая из половин закреплена на подвижных элементах, одни  
15 части которых выполняет роль рефлектора 6 с функцией фокусировки излучения от лампы 4 на зафиксированном между половинами прозрачного диэлектрика 12, например путем элементарного зажима, фрагменте кожи 17. Половины рефлектора объединены с ручками 40, при смыкании которых вокруг оси 41  
20 происходит зажим кожи 17. Устройство с таким наконечником более удобно использовать в домашних условиях.

Как видно из фиг. 5 (а, б, в) внутренняя поверхность рефлектора "щипцов" в сомкнутом состоянии имеет эллиптическую форму. Если в одном фокусе 42 эллипса помещены спираль нити  
25 накала 37, то испускаемое из этой нити излучение 34 после отражения от эллиптической поверхности концентрируется во втором фокусе 43. Искажение хода лучей 34 из-за наличия диэлектрического элемента 12 будет минимальным, если испускаемые из одного фокуса 42 и отраженные от внутренней  
30 поверхности эллипса лучи будут падать на этот элемент нормально. Для этого диэлектрический элемент 12 в сечении должен быть кругом. Возможна и многогранная форма (более технологична при изготовлении). Ориентация граней и их число выбирается в соответствии с условием концентрации максимальной доли  
35 излучения во втором фокусе 43 эллипса.

На фиг. 5а представлены "щипцы" с формой внутренней поверхности 7 рефлектора 6 в виде эллипсоида вращения и спиралью нити накала 37, ориентированной вдоль большой оси 39  
40 эллипсоида. В этом случае излучение нити накала 37 испускается преимущественно перпендикулярно этой оси 39 эллипсоида, и отражаясь от внутренней поверхности 7 рефлектора 6 попадает на диэлектрический элемент 12, который выполнен в форме шара 44 и закреплен с помощью фиксатора 45, со всех сторон и концентрируется в области второго фокуса 43 эллипсоида,  
45 совпадающей с центром 46 шара 44.

На фиг. 5б и 5в представлены "щипцы" с формой внутренней поверхности 7 рефлектора 6 в виде эллиптического цилиндра и спиралью нити накала 37 ориентированной вдоль образующей цилиндра. В этом случае излучение нити накала испускается

преимущественно перпендикулярно образующей цилиндра и, отражаясь от внутренней поверхности 7 рефлектора 6 концентрируется во втором фокусе 43 эллипса. При этом, приведенная на фигурах форма диэлектрического элемента 12 (призма 47 или цилиндр 48) не изменяет направление излучения 34.

На фигуре 6 изображен вариант цилиндрической лампы накаливания 4 с четырьмя нитями накала 37 в одном баллоне, предназначенной для использования в наконечнике с охлаждением. Если нити накала в лампах изготовлены так, что ее геометрические размеры в плоскости, перпендикулярной освещаемой поверхности биоткани 17, намного меньше размеров нити в других направлениях, то излучение от нее испускается преимущественно параллельно этой плоскости. В результате снижаются потери на взаимное перерассеяние излучения одной нити накала на другие и эффективность устройства в целом возрастает. Расположение нескольких нитей накала в одной колбе позволяет в принципе избавиться от направляющих воздушный поток охлаждения трубок, уменьшить тепловые потери через газ, световые потери на колбах и направляющих воздух трубках, а также повысить технологичность изготовления ламп для данного устройства за счет упрощения конструкции токовводов.

На фиг. 7а изображено сечение в плоскости нитей накала изготовленного наконечника, предлагаемого в рамках данного изобретения, а на фиг. 7б - сечение в плоскости главной оптической оси сферической части рефлектора 6. Рефлектор 6 представляет сборную конструкцию из пластин. Четыре галогенные лампы вклеены в кронштейны 49, которые в свою очередь закреплены к пластине рефлектора винтами 50. В экспериментальном макете использовались четыре лампы типа ELS OSRAM. Излучение ламп 4 через стенки колбы и кварцевой трубки 5 прямо, или, отражаясь от покрытых серебром стенок рефлектора, изготовленного из сплава алюминия, попадали через спектральный фильтр, состоящий из рубина, тонкого слоя воды и кварцевой пластины на сапфировый диэлектрический элемент 12, а затем на поверхность кожи. В эксперименте поверхность кожи охлаждалась посредством системы охлаждения на основе элементов Пельтье марки ТВ-17-0,1.

Сечение волновода в контакте с кожей составляло 15х15 мм. В области спектра 650-1200 нм плотность мощности на поверхности кожи на 1 фазе, длящейся 0,5-1 сек составляет 20 Вт/см<sup>2</sup>, а на второй длящейся 0,2 сек - 85 Вт/см<sup>2</sup>. Как показывают расчеты, этой плотности достаточно для повреждения волосистой луковицы.

Вариант устройства, реализованного с одной галогенной лампой, представлен на фиг. 8. В этом устройстве лампа 4 своим наибольшим размером сориентирована горизонтально относительно поверхности кожи 17. Если форма накального тела несимметрична, то колба лампы ориентируется относительно поверхности кожи горизонтально таким образом, чтобы

- поверхность спирали 37 с наибольшей площадью была обращена к поверхности кожи. В данном случае волноводный эффект в направлении распространения излучения от лампы к коже обеспечивается главным образом элементом 51 в виде усеченной пирамиды 51 с высоким значением показателя преломления (не менее 1.76), а в направлении распространения отраженного от кожи излучения - зеркальной поверхностью 52. Пространство между поверхностью элемента 51 и поверхностью 52 образует собой кювету 53, соединенную с трубопроводом 54 заполненным талой водой с температурой  $+1^{\circ}\text{C}$  из резервуара 55, которая поступает в сливной бак 56. Призма 12 выполнена из сапфира, закрепленного в металлической оправе 13, внутри которой предусмотрен проток жидкости с температурой  $0^{\circ}\text{--}5^{\circ}\text{C}$ , образующейся при таянии твердого многокомпонентного вещества, например, замороженного водно-спиртового раствора, помещенного в резервуар 57, который соединен с емкостью 58, где и собирается жидкость с температурой  $0^{\circ}\text{--}5^{\circ}\text{C}$ . Блок питания и управления 3 при данной реализации предлагаемого устройства может иметь в своем составе систему обратной связи, состоящую из исполнительного устройства и датчика (на чертеже не указан).
- Форма отражающей поверхности 7 рефлектора 6 и ее расположение в непосредственной близости к лампе 4 выбирается таким образом, чтобы длина оптического пути между излучающей поверхностью накального тела 37 лампы 4 и обращенной к ней поверхностью волновода 51 была минимальной и обеспечивала наибольшую светопередачу. Волновод 51 максимально эффективно, за счет явления полного внутреннего отражения, передает свет от поверхности 7 через жидкий фильтр и сапфировую пластину на поверхность кожи. Жидкий фильтр избирательно поглощает ИК компоненту излучения лампы, ослабляя интенсивность света в этой области спектра до оптимального уровня. Жидким фильтром является вода образующаяся при таянии льда в резервуаре 55 и под небольшим давлением попадающая в кювету 53, нагретая ИК излучением вода фильтра по трубопроводу попадает в сборную емкость для талой воды. Резервуар 55 и сборная емкость 56 для талой воды являются сменными элементами. Сапфировая пластина 12 охлаждается до температуры порядка  $0^{\circ}\text{--}5^{\circ}\text{C}$  при протекании жидкости образующейся при таянии твердого многокомпонентного вещества (например замороженного водно-спиртового раствора) в резервуаре 57 по трубопроводам 59 расположенным внутри металлической оправы 13. Резервуар 56 и сборная емкость 58 для жидкости с температурой  $0^{\circ}\text{--}5^{\circ}\text{C}$  также являются сменными элементами. Таяние льда и твердого многокомпонентного вещества начинается при помещении резервуаров 55 и 57 из холодильного устройства в устройство и происходит за счет притока тепла из окружающей среды при комнатной температуре. Необходимость использования жидкости с температурой  $0^{\circ}\text{--}5^{\circ}\text{C}$  связана с необходимостью предохлаждения, например эпидермиса, до

температуры ниже 0°C при его соприкосновении с сапфировой пластиной 12 и металлической оправой 13 до, в процессе и после облучения. Таяние является фазовым переходом, что позволяет наиболее эффективно аккумулировать тепло от кожи и жидкого

5 фильтра.

Лампа электрически питается от блока питания, создающего электрические импульсы требуемого напряжения, тока и длительности. Блок питания может быть автономным, за счет помещения в его состав электролитического одно- или

10 многозарядного аккумулятора.

Необходимо отметить, что процедура обработки может быть болезненна. Для повышения комфортности и снижения травматичности в состав устройства введена система обратной связи. В простейшем варианте она состоит только из

15 исполнительного устройства, типа кнопочного переключателя или педали, прекращающего подачу электропитания по желанию пациента и может управляться пациентом. Возможны варианты когда в качестве датчика фиксирующего превышение порога боли выступает датчик размера зрачка глаза (при превышении порога

20 боли зрачок резко сокращается), скорости кровотока (при превышении порога боли скорость кровотока резко падает), значения температуры обрабатываемой поверхности (при превышении порога боли температура достигает определенного значения), по сигналам с которого исполнительное устройство

25 изменяет ток через протекающий через лампу или прекращающего подачу электропитания.

При использовании данного устройства фаза предохлаждения может занимать значительный промежуток времени, при этом излучение лампы отсутствует и появляется лишь

30 при достижении эпидермисом температуры близкой 0°--5°C, о чем свидетельствует поступающий с температурного датчика (термопары, терморезистора, радиометрического датчика и т.д.) сигнал.

В случае необходимости обработки биоткани с достаточно

35 большой площадью поверхности возможно одновременное использование нескольких подобных устройств, выходы которых образуют матрицу излучателей-охладителей находящихся в контакте с кожей .

## Формула изобретения.

1. Устройство для терапевтической и косметологической фотообработки биоткани, содержащее блок питания (3) и помещенные в корпус источник электромагнитного излучения (34), выполненный в виде лампы накаливания (4), рефлектор (6) для концентрации этого излучения (34) на обрабатываемую биоткань (17), прозрачный диэлектрик (12) в виде волновода, соединенный с системой охлаждения и находящийся в контакте с обрабатываемой биотканью (17), а также спектральный фильтр, отличающееся тем, что лампа накаливания (4) соединена с блоком питания (3) через модулятор (30), который содержит измеритель сопротивления (38) нити накала (37) лампы (4) и регулятор мощности, а внутренняя поверхность рефлектора (6) представляет собой зеркальную поверхность (7), выполненную с дополнительной функцией возврата излучения (34), отраженного от обрабатываемой биоткани, обратно к биоткани (17).
2. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что спектральный фильтр может быть выполнен в виде поглощающего фильтра (8).
3. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что спектральный фильтр может быть выполнен в виде люминесцентного преобразователя (9).
4. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что спектральный фильтр может быть выполнен в виде отражающего покрытия (7) рефлектора (6).
5. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что прозрачный диэлектрик (12) расположен в металлической оправе (13), закрепленной внутри корпуса (1), к которой с одной стороны вплотную присоединена, находящаяся в контакте с биотканью (17) металлическая пластина (16), соединенная с системой охлаждения (33).
6. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что поглощающий излучение фильтр (8) выполнен в виде, образующей с диэлектриком оптический волновод, сэндвич структуры: люминесцентный преобразователь (9) - охлаждающая незамерзающая жидкость (10), оптический теплоизолятор (11).
7. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что область внутренней поверхности рефлектора (6), расположенная над лампой накаливания (4), имеет форму части эллипсоида или сферы с центром кривизны в центре ближайшей к лампе (4) грани (36) волновода, а область внутренней поверхности рефлектора (6), расположенная между лампой накаливания (4) и этой гранью наклонена к последней под тупым углом.



8. Устройство для терапевтической и косметологической фотообработки биоткани по п.7, отличающееся тем, что область внутренней поверхности рефлектора (6), расположенная между лампой накаливания (4) и ближайшей к ней гранью (36) волновода (8) представляет собой боковую поверхность усеченных конуса или правильной четырехугольной пирамиды, малым основанием которых является указанная грань, а двугранный угол между ней и боковой поверхностью или гранью лежит в пределах от  $115^\circ$  до  $120^\circ$ .
9. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что рефлектор (6) и прозрачный диэлектрик (12) выполнены из двух половин с общей осью вращения (39), на одной из половин рефлектора (6) с внутренней стороны расположена лампа накаливания (4), каждая из половин прозрачного диэлектрика (12) может быть выполнена с функцией спектрального фильтра и закреплена на соответствующей половине рефлектора (6) с учетом размещения биоткани (17) между половинами диэлектрика (12), в сомкнутом состоянии половин рефлектора (6).
10. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что внутренняя поверхность рефлектора (6), в сомкнутом состоянии его половин, представляет собой эллипсоид вращения, в одном его фокусе (47) расположена спираль нити накала (37) лампы (4), ось которой ориентирована вдоль большой оси (39) эллипсоида, половины прозрачного диэлектрика (12) выполнены в виде шаровых сегментов (44), с основаниями параллельными большой оси эллипсоида и оси вращения половин рефлектора (6), шаровые сегменты закреплены на половинах рефлектора с учетом совпадения их общего центра со вторым фокусом (43) эллипсоида и расположенной между шаровыми сегментами биотканью (17).
11. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что внутренняя поверхность рефлектора (6), в сомкнутом состоянии его половин, представляет собой поверхность эллиптического цилиндра, образующая которого параллельна оси вращения половин рефлектора (6), на уровне одного фокуса эллипса расположена спираль нити накала (37) лампы (4), ось которой ориентирована параллельно образующей эллиптического цилиндра, а половины прозрачного диэлектрика (12) выполнены в виде половин цилиндра (48), закрепленных на половинах рефлектора (6) с учетом совпадения оси этого цилиндра с расположенной, между его половинами биотканью (17) и второй фокальной осью (43) эллиптического цилиндра, причем направление образующей цилиндра (48) диэлектрика (12) совпадают с направлением ориентации оси спирали нити накала (37).

12. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что внутренняя поверхность (7) рефлектора (6), в сомкнутом состоянии его половин, представляет собой поверхность эллиптического цилиндра, образующая которого параллельна оси вращения (39) половин рефлектора (6), на уровне одного фокуса (42) эллипса расположена спираль нити накала (37) лампы (4), ось которой ориентирована параллельно образующей цилиндра, а половины прозрачного диэлектрика (12) выполнены в виде прямых призм (47), с неправильными многоугольниками в основании, ориентированных боковыми ребрами параллельно оси вращения (39) половин рефлектора (6), закреплены призмы (47) так, что фокальная ось (39) эллиптического цилиндра совпадает с расположенной между призмами (47) биотканью (17).
13. Устройство для терапевтической и косметологической фотообработки биоткани по п.4, отличающееся тем, что зеркальная поверхность (7) рефлектора (6) выполнена из материала, селективно отражающего излучение (34) с длиной волны в диапазоне 600÷2500нм.
14. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что число ламп накаливания (4) или число нитей накала (37) в одной лампе (4) может быть больше одной, причем нити накала (37) могут быть плоскими.
15. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что охлаждающая незамерзающая жидкость (10) дополнительно обладает свойствами поглощения излучения или переизлучения в другую область спектра и помещена в трубопровод (22), соединенный с нагнетающей помпой (33).
16. Устройство для терапевтической и косметологической фотообработки биоткани по п.1., отличающееся тем, что пространство внутри рефлектора (6) соединено с воздухопроводом подключенным к воздушному компрессору (31).
17. Устройство для терапевтической и косметологической фотообработки биоткани по п.1., отличающееся тем, что система охлаждения (33) прозрачного диэлектрика (12) и металлической пластины может содержать элементы Пельтье (14).
18. Устройство для терапевтической и косметологической фотообработки биоткани по п. 3, отличающееся тем, что люминесцентный преобразователь (9) и оптический теплоизолятор (11), входящие в сэндвич-структуру, выполнены соответственно из рубина или сапфира с титаном и оптического стекла, в том числе кварцевого.
19. Устройство для терапевтической и косметологической фотообработки биоткани по п.1., отличающееся тем, что оно

дополнительно снабжено системой водяного или воздушного охлаждения корпуса.

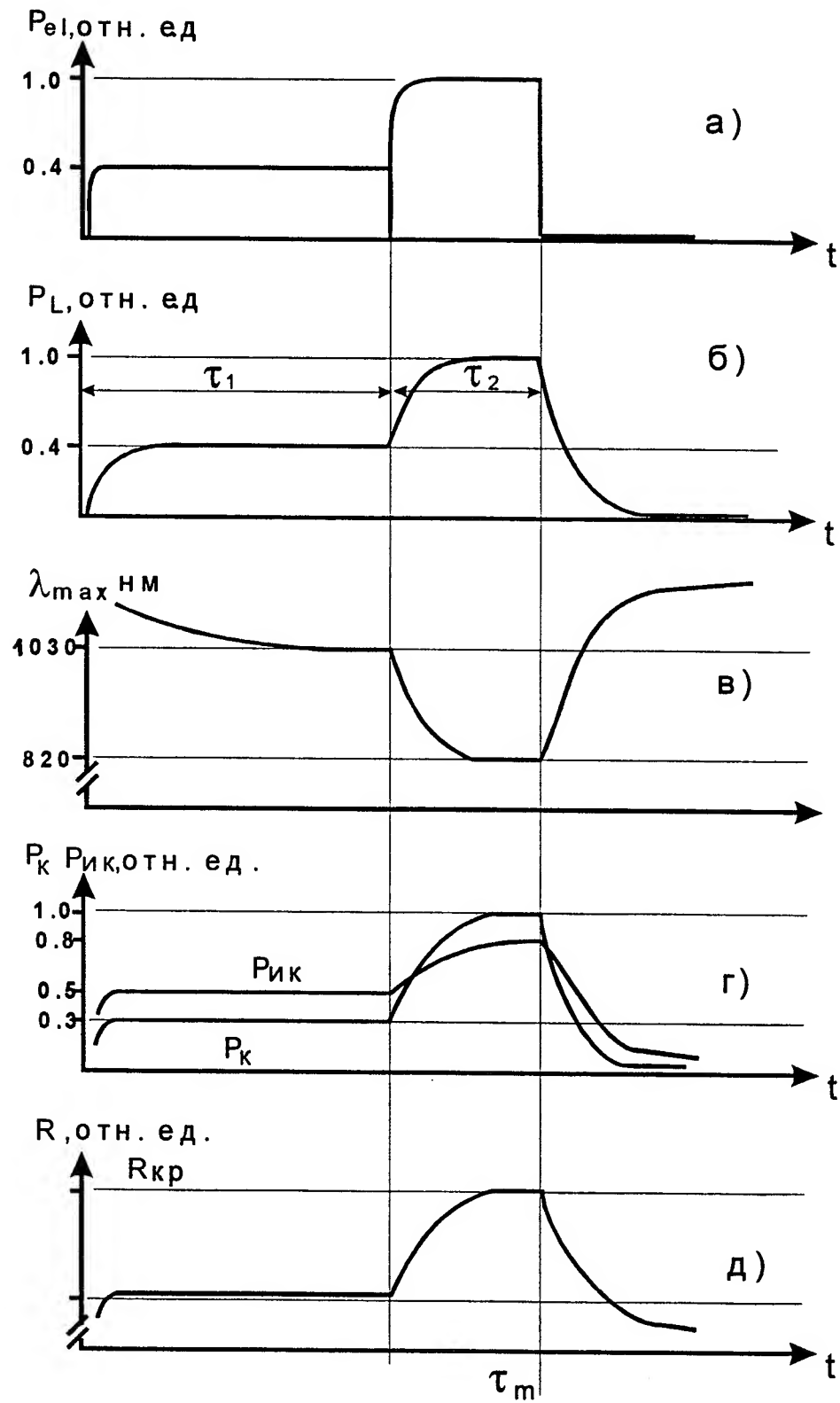
- 5 20. Устройство для терапевтической и косметологической фотообработки биоткани по п. 3, отличающееся тем, что в нем баллон лампы накаливания (4) и/или трубка (5) окружающая баллон (4) дополнительно выполнены с функцией люминесцентного преобразователя.
- 10 21. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что нить накала (37) лампы (4) представляет собой плоский излучатель, плоскость которого параллельна плоскости обрабатываемой биоткани, а часть внутренней поверхности рефлектора (6) расположенная над лампой находится от ближайшей к лампе (4) грани (36) волновода на расстоянии не более  $1.2d$  где  $d$  -
- 15 внешний диаметр колбы лампы.
- 20 22. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что поглощающий излучение фильтр выполнен в виде сэндвич-структуры с функцией волновода для излучения от лампы (4) к биоткани (17) и обратно, и образованной в направлении перпендикулярном поверхности биоткани из четырехугольной усеченной пирамиды (51) изготовленной из прозрачного материала с показателем преломления не менее чем 1.76, большее основание которой, обращено к лампе (4), воды с
- 25 температурой от  $1^{\circ}\text{C}$  до  $10^{\circ}\text{C}$  и прозрачного диэлектрика кубической формы, находящегося в контакте с биотканью, а в направлении, параллельном поверхности биоткани - из той же четырехугольной усеченной пирамиды (51), воды с температурой от  $1^{\circ}\text{C}$  до  $10^{\circ}\text{C}$  и внутренней поверхностью (52) наконечника с
- 30 зеркальным покрытием.
23. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что прозрачный диэлектрик (12) расположен в металлической оправе, снабженной системой охлаждения жидкостью с
- 35 температурой от  $-1^{\circ}\text{C}$  до  $-18^{\circ}\text{C}$ .
24. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что оно дополнительно снабжено системой обратной связи, в цепь которой входит датчик болевого порога пациента, нить накала
- 40 (37) лампы (4) и блок питания (29).
25. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что оно дополнительно снабжено прерывателем света управляемого по болевому порогу пациентом или датчиком боли в виде
- 45 иридодиагностики или диагностики кровотока.
26. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что блок питания (29) снабжен аккумулятором.

27. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34), лампы накаливания (4) отличающийся тем, что для фотодеструкции волосяной луковицы (35), облучение производят двумя фазами, первая из которых предназначена для предварительного нагрева дермиса (17) до температуры не выше температуры денатурации и длится 0,1÷100сек в диапазоне 1100-2500 нм с максимумом в области 1300-1400 нм и плотностью мощности от 10 - 60 Вт/см<sup>2</sup>, а вторая, непосредственно следующая за первой, предназначена для деструкции волосяной луковицы (35) и длится 0.05-10 сек в диапазоне 600-1200 нм с максимумом в области 600-1000 нм и плотностью мощности от 80 - 800 Вт/см<sup>2</sup>.
28. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34), лампы накаливания (4) отличающийся тем, что для фотодеструкции волосяной луковицы (35), облучение длится 0.05-10сек в диапазоне 600-1200 нм с максимумом в области 600-1000 нм и плотностью мощности от 80 - 800 Вт/см<sup>2</sup>.
29. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают затем, продолжая охлаждать, облучают светом (34) лампы накаливания (4), отличающийся тем, что для фотокоагуляции кровеносных сосудов или вен облучение производят в две фазы, первая из которых предназначена для предварительного нагрева дермиса (17) до температуры не выше температуры денатурации и длится 0.1-100 сек в диапазоне 500-2500 нм с максимумом в области 700- 1500 нм и плотностью мощности от 1 до 50 Вт/см<sup>2</sup>, а вторая, непосредственно следующая за первой, предназначена для коагуляции сосуда или вены и длится 0.05-1 сек в диапазоне 400-1200нм с максимумом в области 500-1100 нм, с плотностью мощности от 10 до 500 Вт/см<sup>2</sup>.
30. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34) лампы накаливания (4), отличающийся тем, что для селективного повреждения коллагена дермиса (17) с целью стимуляции его регенерации или селективного повреждения подкожного жира облучение производят светом в диапазоне 600-2500 нм с длительностью 0.1-1000 сек и плотностью мощности от 0.1 до 500 Вт/см<sup>2</sup>.
31. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34) лампы накаливания (4), отличающийся тем, что прозрачный диэлектрик (12) и металлическую пластину (16) устройства по п. 5 приводят в термический контакт с кожей (17), затем, устройство одновременно с облучением или в промежутках между облучениями перемещают вдоль поверхности кожи (17) так, что

новый необлученный участок кожи (17) сначала соприкасается с металлической пластиной (16), а затем с прозрачным волноводом (12).



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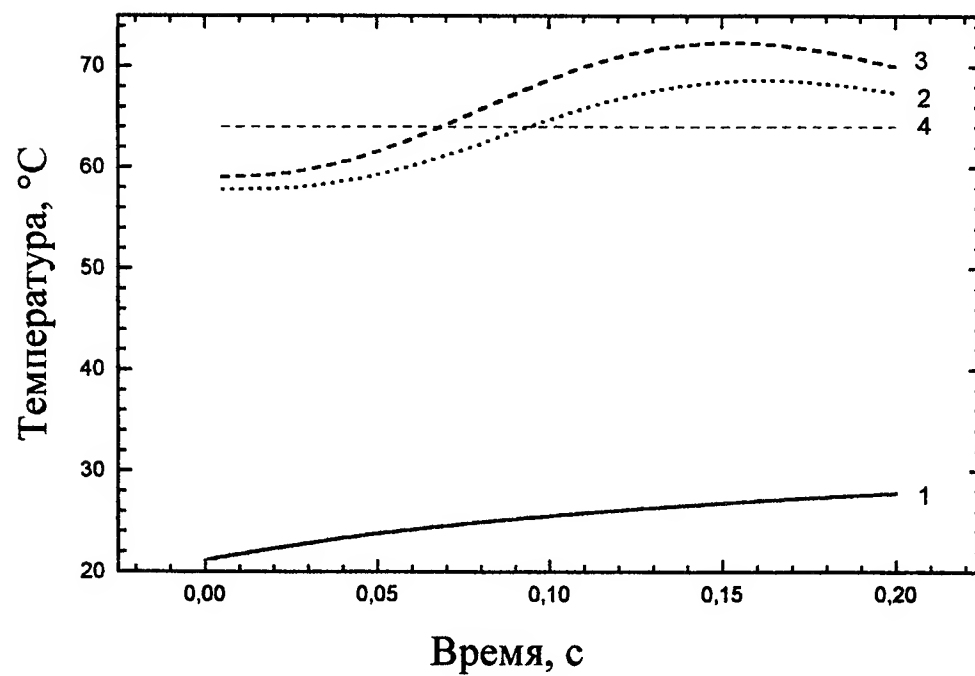


Фиг. 2

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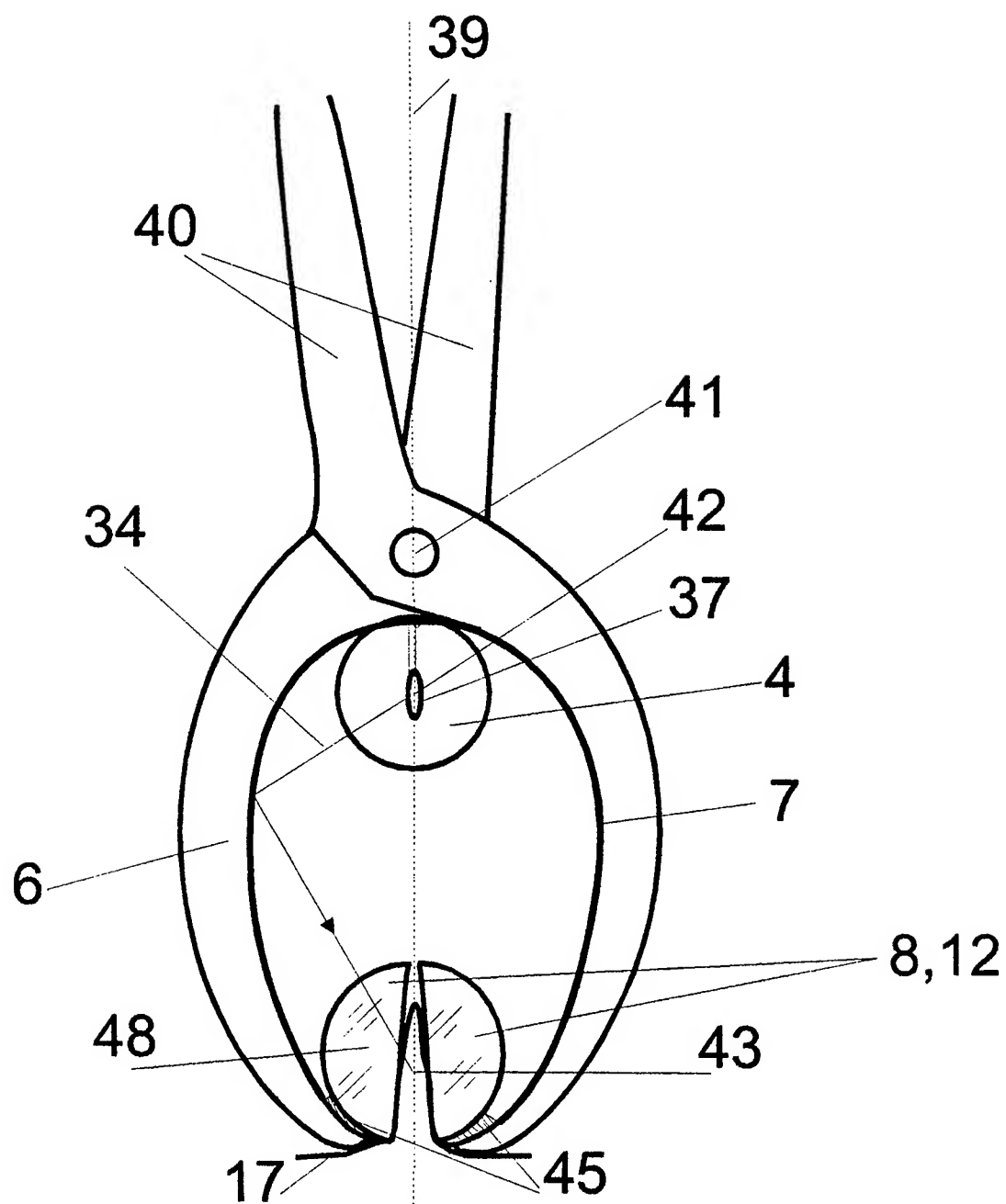
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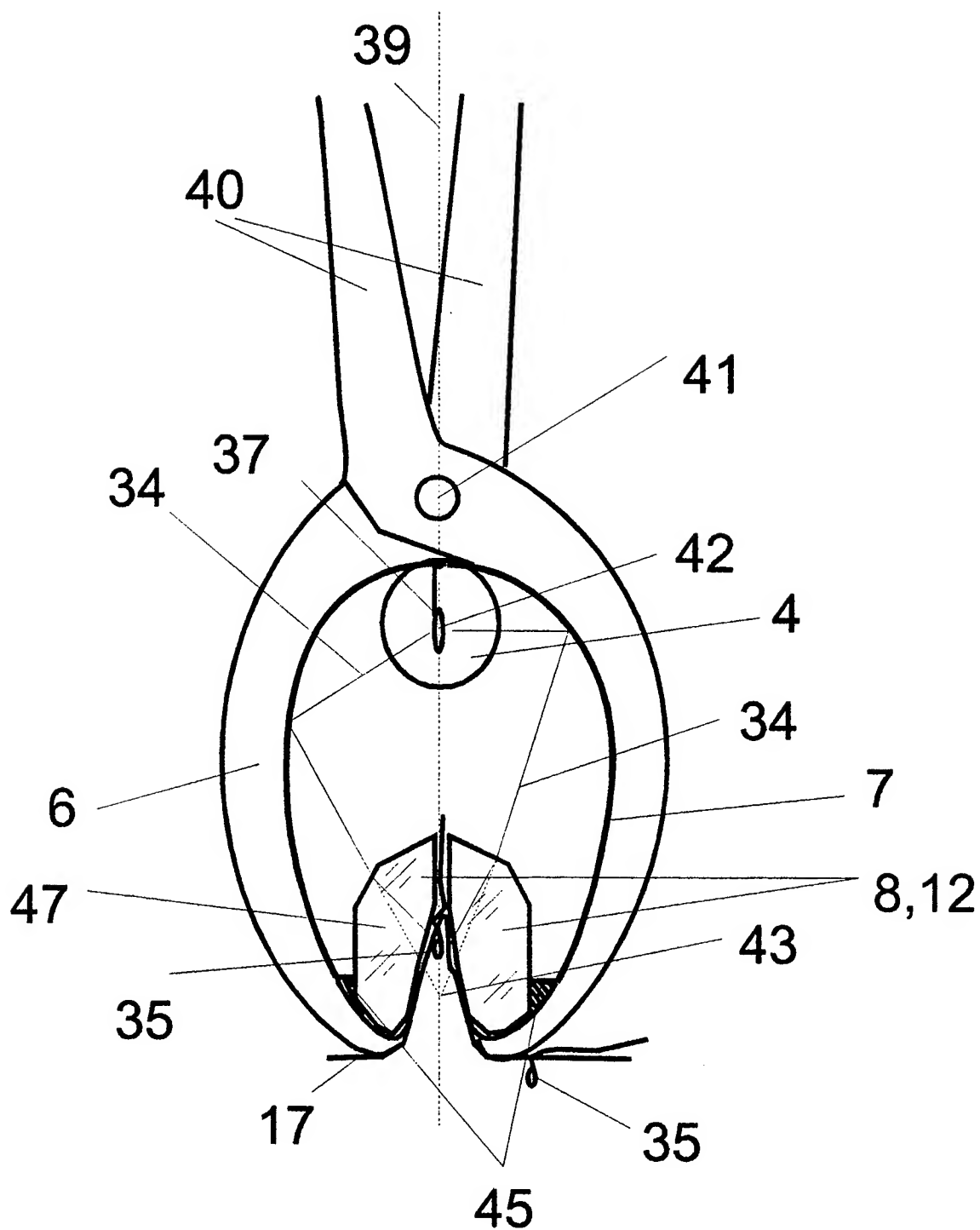
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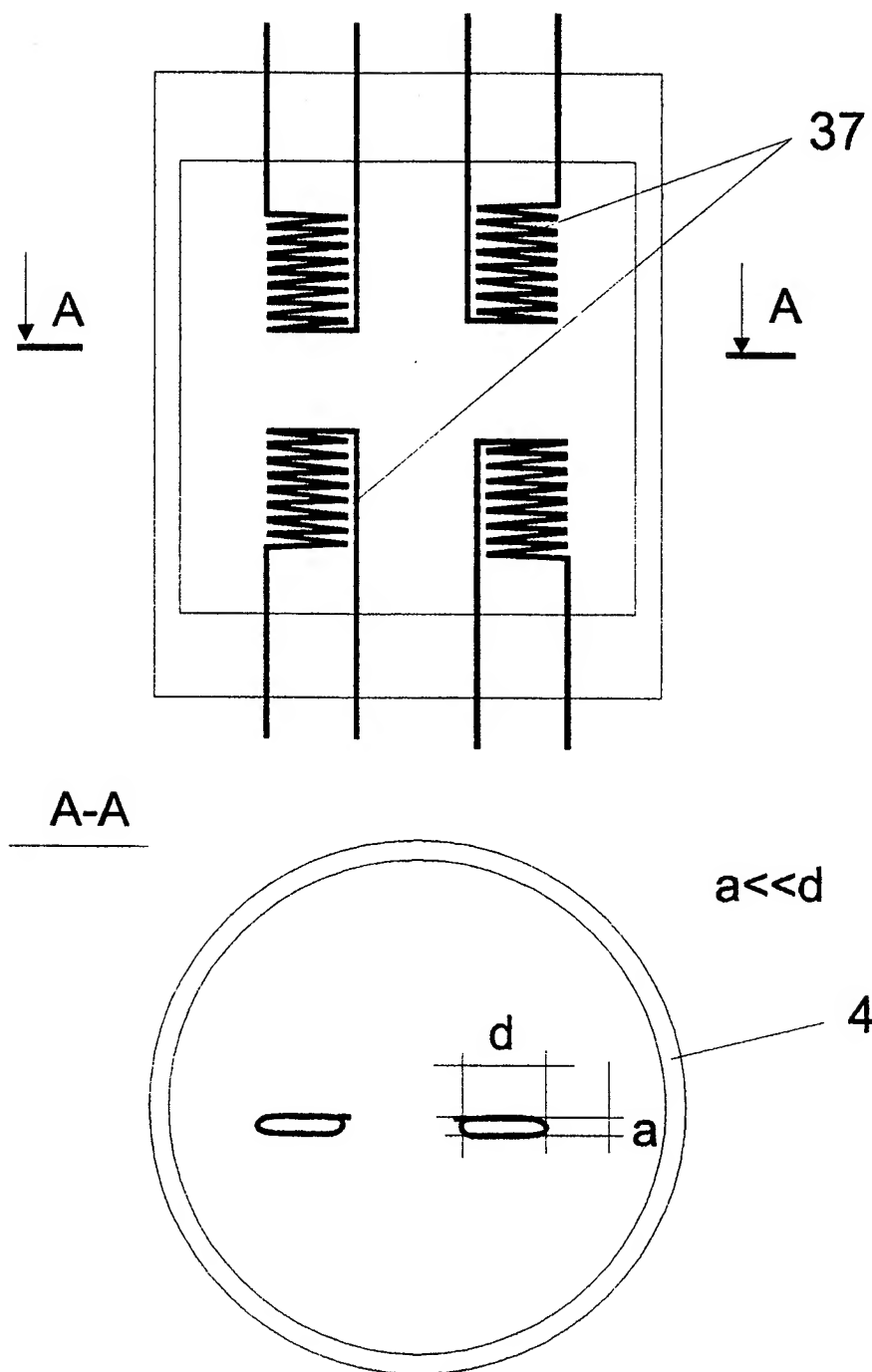


Фиг. 56.

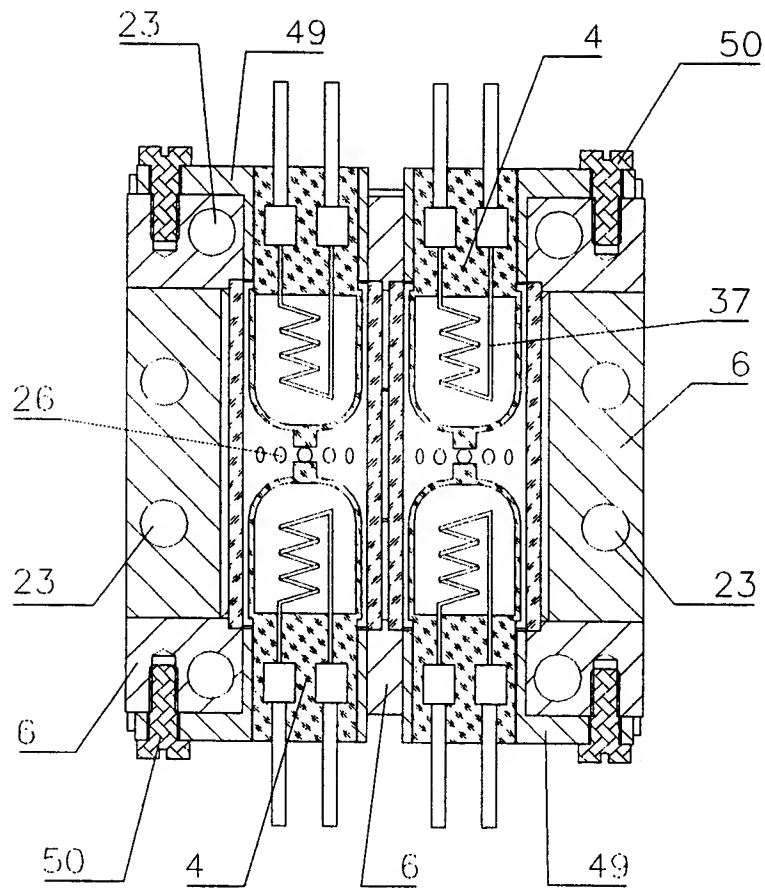


Фиг.5в.

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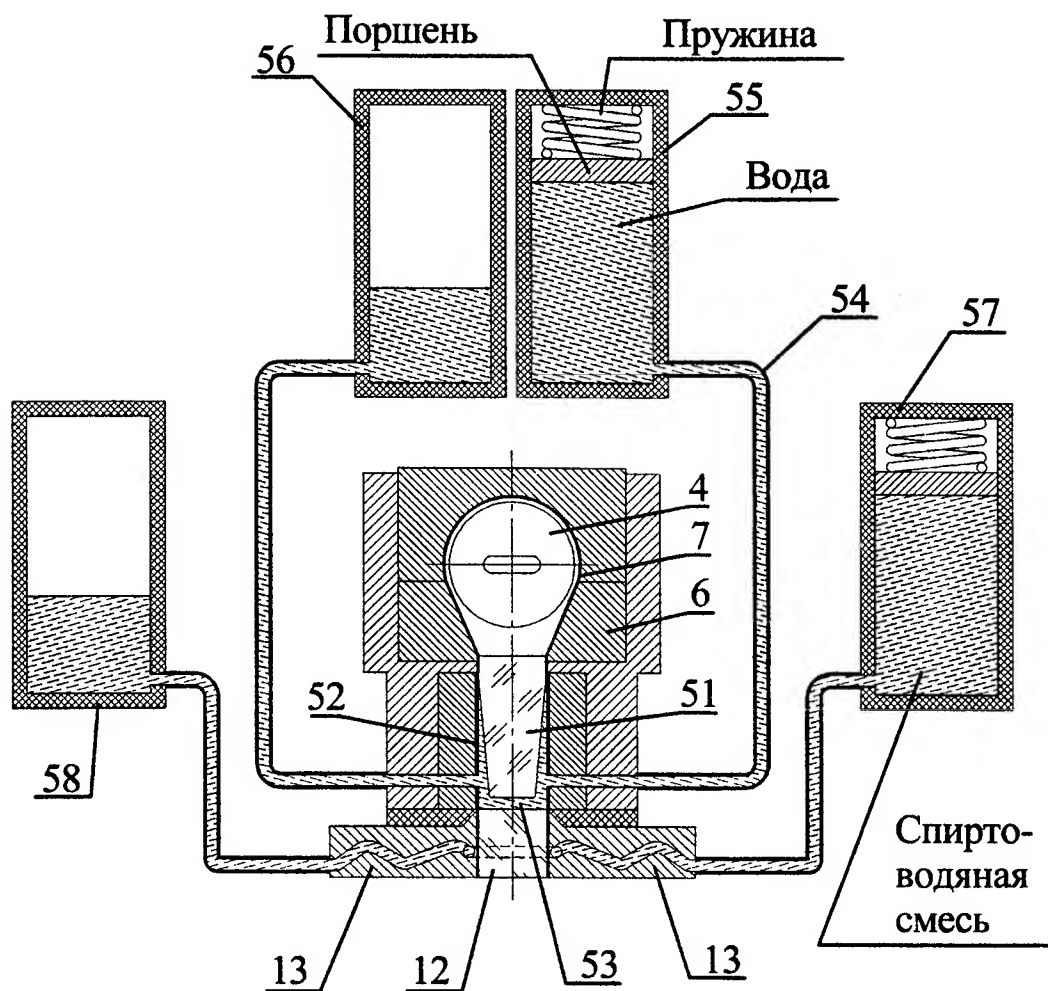


Фиг.6.



Фиг. 7а.





Фиг 8.



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : <b>A61B 18/20</b>	<b>A2</b>	(11) International Publication Number: <b>WO 00/54685</b> (43) International Publication Date: 21 September 2000 (21.09.00)
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(21) International Application Number: PCT/US00/06563

(22) International Filing Date: 13 March 2000 (13.03.00)

## (30) Priority Data:

09/270,118	15 March 1999 (15.03.99)	US
09/357,745	20 July 1999 (20.07.99)	US
09/393,830	10 September 1999 (10.09.99)	US

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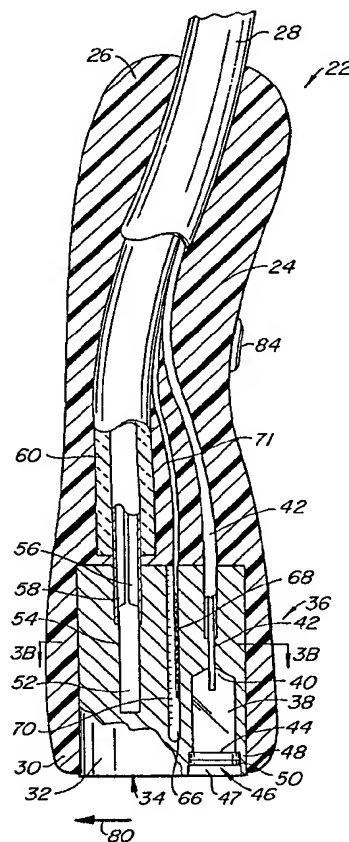
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published***Without international search report and to be republished upon receipt of that report.*

(54) Title: HAIR REMOVAL DEVICE AND METHOD

## (57) Abstract

A hair removal device (22) includes a cooling surface (34) which is used to contact the skin (6) prior to exposure to hair tissue-damaging laser light (74) passing from a radiation source (36) through a recessed window (46). The window is laterally offset from the cooling surface and is spaced apart from the cooling surface in a direction away from the patient's skin to create a gap between the window and the skin. The window preferably includes both an inner window (46) and an outer, user-replaceable window (48). The laser-pulse duration is preferably selected according to the general diameter of the hair.





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## HAIR REMOVAL DEVICE AND METHOD

### BACKGROUND OF THE INVENTION

5           Use of light to denature very specific kinds of tissue has been called wavelength-selective photo-thermolysis. The use of lasers for this purpose has been well described in the literature. See, for example, R.G. Wheland, "Laser-assisted hair removal", Lasers in Dermatology, Vol. 15, pp. 469-477, and references cited. By choosing a laser with the right wavelength and energy per unit area (fluence), a particular  
10   light-absorbing target substance (chromophore) in living tissue, such as melanin or hemoglobin, will absorb energy from the laser beam and become hot enough to destroy functionality in the tissue containing the chromophore. Tissue in the same area that does not have high concentration of the target chromophore will not be affected.

          Hair includes two basic parts, the shaft, which is the portion of the hair  
15   above the epidermis, and the root, which is the portion below the surface of the epidermis. Various tissues surround the root of the hair. Hair color is primarily do to the presence of melanin in the hair. Melanin is created at the base of the hair follicle and is passed into the hair as it grows. The presence of melanin has made it possible to use lasers and other light sources for hair removal with melanin as the target chromophore. The hair follicle  
20   and surrounding structure (referred to collectively as hair tissue) are selectively heated when the melanin in the hair tissue and in the hair root itself and is exposed to treatment radiation. The hair tissue is thermally damaged so that a result of the localized heating, many of the exposed hairs later atrophy and are sloughed from the epidermis.

          The early work in this field was centered around a wavelength with very  
25   high melanin absorption, the pulsed ruby laser (694nm). Long pulse ruby lasers (as opposed to Q-switched ruby lasers) typically have a pulse duration in the 1 millisecond range. Although the wavelength is highly absorbed in melanin, the wavelength selection has significant limitations with darker skin types as the epidermis can blister from the superficial melanin heating.

30           Many different approaches to hair removal have been explored since the early ruby laser evaluation. A common trend is a continual shift towards longer wavelengths, which have less melanin absorption, as it allows treatment of patients with a

darker range of skin tones. Initially, alexandrite (755nm) was evaluated and later a diode approach (810nm). The alexandrite laser offers improved clinical capabilities over the ruby laser if one considers treatment of darker skin types. However, from engineering and system performance measures, the two systems are similar in terms of size, utility  
5 requirement, treatment speed, and system cost. In contrast, the high pulse energy diode laser allows the system to be much smaller than previous systems with an ability to run off of standard power. One commercially-available system, sold by Coherent of Santa Clara as Lightsheer, weighs in the 45kg (100 pound) range and allows the physician to treat the darkest skin types with minimal risk of post operative blistering. Unfortunately,  
10 the high pulse energy diode approach is very expensive as it requires up to 100 diode bars to achieve the peak powers needed for the desired clinical result. Another limitation with this approach is in the delivery device. The current Lightsheer system houses all diodes and associated hardware in a handpiece that is used in direct contact with the skin. This approach results in a heavy handpiece, weighing several pounds, that causes user fatigue  
15 and an overall bulky design.

Dermatologists have used cooling devices in dermatologic applications prior to laser treatment. The purpose is to chill the skin with the understanding that exposure to treatment radiation will elevate the epidermal temperature. Chilling lowers the initial temperature so that the post treatment temperature at the epidermis will not  
20 create a heat-induced blister. U.S. Patent 5,735,844 describes apparatus which uses a cooled lens, through which radiation passes, pressed against the patient's skin to cool the epidermis.

#### SUMMARY OF THE INVENTION

The present invention is directed to a hair removal device and method by  
25 which hair tissue-damaging radiation passes from a radiation source through a recessed window to the patient's skin. The hair removal device also includes a skin-cooling element having a cooling surface which is used to contact the skin prior to exposure of that skin area to the radiation. The window is laterally offset from the cooling surface as well as spaced apart from the cooling surface in a direction away from the patient's skin  
30 so to create a gap between the window and the patient's skin.

The presence of a gap between the window of the radiation source and the patient's skin offers several benefits. One problem associated with a contact cooling window in direct contact with the skin is debris build up. Dermatologic tissue

accumulates on the contact window as treatment pulses are delivered. The window must be periodically wiped in order to preserve the window from local, intense overheating that thermally and mechanically stresses the window and causes pitting. A recessed window does not exhibit this problem. Another advantage is that the window can be kept warm and above the local dewpoint temperature for both the inner and outer surfaces, so water and other condensables do not collect on it. Since the window is not in contact with the skin, it does not cause any re-heating of the pre-cooled skin.

In one embodiment of a hair removal device the radiation source includes an optical chamber having an exit aperture covered by the recessed window and an optical fiber entrance in which an optical fiber can be housed to permit tissue-damaging radiation to pass from the optical fiber into the optical chamber. The optical chamber may have reflective sidewalls to help equalize radiation fluence; a total internal reflecting optical element, such as a fused silica block, may be used to reduce losses. The optical chamber may also be heated to help prevent condensation from forming on the walls of the chamber or the window. A moisture wicking element may be used to wick condensation away from cooled surfaces adjacent the optical chamber to a heat sink or other heated element where the moisture evaporates. The window may include both an inner window and an outer, user-replaceable window; if the outer window becomes damaged through use, it can be easily replaced without affecting the integrity of the optical chamber. This is an advantage over fixed, single window designs that are rendered unusable if there is a surface imperfection due to, for example, localized pitting.

The hair removal device may be coupled to a laser which supplies laser light to the radiation source for passage through the recessed window. The laser may be controlled by user-operated laser power inputs including a laser-pulse duration input and one of a laser-pulse amplitude input and a laser-pulse fluence input. The laser-pulse duration input may be adjusted according to the diameter of the hair, which corresponds to the thermal relaxation time of the hair. Therefore, smaller diameter hairs will typically call for shorter laser-pulse duration inputs while larger diameter hairs will call for a longer laser-pulse duration inputs. Although larger diameter hairs will be selectively heated with short pulses, defined as a pulse duration shorter than the thermal relaxation time of hair, the peak power on the epidermis is unnecessarily higher than it needs to be. This can result in a heat-induced blister.

Another aspect of the invention relates to a method for preparing a hair-removal device for use including the steps of (1) determining the diameter typical of the hair to be removed, and (2) selecting a laser-pulse duration for a hair removal device according to this diameter of the hair so that smaller diameter hair results in a shorter laser-pulse duration than larger diameter hair. This aspect may be supplemented by the step of (3) applying laser energy through a window of a hair removal device of the selected laser-pulse duration to a patient's skin to cause thermal injury to hair tissue. This applies to both individual hairs and a plurality of hairs.

The methods may include selecting a chosen one of a laser-pulse amplitude and a laser-pulse fluence prior to the applying step. Further, the hair-removal method may also include positioning a cooling element of the hair removal device against a first target area and then moving, after a period of time, the cooling element from the first target area to a second target area so that the window overlies and is spaced apart from the first target area; laser energy is then applied to the first target area through the window with the window overlying and spaced apart from the first target area.

The pulse duration has been shown to have significant clinical implications. A short pulse, typically in the sub-5ms, range creates high peak powers because high fluence is required to deliver enough energy to achieve the proper clinical endpoint. High peak power tends to heat the epidermis. Longer pulses result in lower peak power.

Shorter wavelengths, such as 694nm, do not penetrate deeply into the patient's skin so, some believe, that it may be desirable, with such shorter wavelengths, to use a convex window pressing against the skin to shorten the path from the window to the hair tissue as is taught by U.S. Patent No. 5,735,844 patent. It has been found that by the use of longer wavelengths which are still absorbed by melanin, such as 800 to 1200nm, it is not necessary for the window of the radiation source to press against the patient's skin to effectively irradiate the hair tissue at a target area.

Another aspect of the invention is the recognition that it is not necessary to cool the skin the same time it is being irradiated. This is because once the skin has been cooled through contact with a cold surface, removal of the cold surface permits the skin to warm up but it does so much more slowly than it has cooled down because it is relying almost entirely on convection rather than conduction. Recognizing the fact that the skin remains sufficiently cool for a second or two after removal of the cooling surface permits

the window of the radiation source to be positioned spaced apart from the surface of the skin. This eliminates some problems created when the window of the radiation source directly contacts the skin during irradiation, such as window surface damage caused by intense heating from hair fragments that are heated by the laser beam.

5 A further aspect of the invention is the recognition that radiation in the longer wavelengths (about 800 to 1200nm) of the band of melanin-absorbing radiation, typically considered from about 600nm to 1200nm, can be used without the need for the use of chromophore contaminants as taught by U.S. Patent 5,425,728.

Other features and advantages of the invention will appear from the  
10 following description in which the preferred embodiments have been set forth in detail in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a simplified cross-sectional view of a hair with its root within a  
15 hair follicle;

Fig. 2 plots absorption coefficient versus wavelength for different substances including melanin;

Fig. 3 is a schematic representation of a hair removal assembly made according to the invention;

20 Fig. 3A is a simplified side view of the hair removal device of Fig. 3 with portions broken away to show internal detail;

Fig. 3B is a simplified cross-sectional view taken along line 3B-3B of Fig. 3A;

Fig. 4 is a bottom plan view of the hair removal device of Fig. 3A;

25 Fig. 4A is an overall view of the lower end of an alternative embodiment of the hair removal device of Fig. 3A;

Fig. 5 is a theoretical plot of fluence versus radial position for a diverging beam;

30 Fig. 5A shows an idealized plot of how to square off or equalize the fluence of the beam of Fig. 5;

Fig. 6 is a simplified view of the radiation source of Fig. 3 showing how radiation is reflected from the walls of the reflective chamber to help equalize radiation intensity and reduce hot spots;

Fig. 7 shows several idealized plots of temperature versus depth below the skin surface;

Figs. 8A, 8b, 8C and 8D are two isometric views, a top plan view and an end view of another alternative embodiment of the hair removal device of Fig. 3A with the ergonomically shaped body removed;

Fig. 9 is a simplified partial cross-sectional view of an alternative embodiment of the hair removal device of Fig. 3A in which the device is configured to permit the user to see the skin area being treated;

Fig. 10 is a simplified view of the bottom of a further alternative embodiment of the hair removal device of Fig. 3A showing leading and trailing cooling surfaces;

Fig. 11 is a partial cross-sectional side view of a hair removal device similar to that of Figs. 8A-8D but including a total internal reflecting optical element to help reduce laser radiation losses;

Fig. 12 is an embodiment similar to that of Fig. 11 but also including a moisture wicking element to help remove condensation which may be produced along the reflecting chamber adjacent to the cooled copper block; and

Fig. 13 is a simplified cross-sectional view taken along line 13-13 of Fig. 12.

## DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Fig. 1 illustrates, in simplified form, a hair 2 including a shaft 4 extending above skin surface 6 and a root 8 extending below the skin surface. The root 8 passes through epidermis 10 into dermis 12 with the base of the root being about 4mm below surface 6. Root 8 is housed within hair follicle 14, hair follicle 14 being surrounded by various tissues including connective tissue sheath 16 and blood vessels 18. The various tissues closely surrounding root 8 and connected with the growth of hair 2, including hair follicle 14 and connective tissue sheath 16, are collectively referred to as hair tissue 20 in this application.

Because melanin is also present in epidermis 10, with darker skin types having more melanin than lighter skin types, it is important that the wavelength be long enough so that absorption is low for the moderate concentrations in melanin in the epidermis to permit most of the light to pass through to the root 8 and hair tissue 20 where

melanin concentrations are relatively high compared to the epidermis. Therefore, it is preferred to use wavelengths in the 800 to 1200nm range; in particular, an Nd:YAG (neodimium-doped YAG) laser having a wavelength of 1.06 micron is preferred because it is a relatively efficient source and the technology is well developed and readily available.

Fig. 3 illustrates, schematically, a hair removal assembly 21 including a hand-held hair removal device 22, device 22 shown in more detail in the simplified views of Figs. 3A and 3B. Device 22 includes a hand-grippable body 24 having an upper or outer end 26 into which an umbilical cable 28 passes. Body 24 also has a lower or skin contacting end 30 housing a formed copper block 32, block 32 having various cavities to provide various features and functions as described below. Block 32 defines a cooling surface 34, see also Fig. 4, which is used to contact the patient's skin and cool the skin and prior to irradiation. Surface 34 is a low friction, high lubricity surface to help prevent bonding between the cooling surface and the skin.

Copper block 32 also houses a radiation source 36. Radiation source 36 includes a reflective chamber 38, in this embodiment having a square cross-sectional shape. Reflective chamber 38 has its walls covered with a highly reflective material, such as gold; the material is chosen for its reflective qualities for the particular wavelength radiation to be used. Other materials, such as dielectric layers combined with high-reflectivity metals, could also be used. Chamber 38 has an optical fiber entrance 40 to permit an optical fiber 42, or a bundle of optical fibers, to extend into chamber 38. The opposite end of chamber 38 has an exit aperture 44 covered by a recessed window 46. Recessed window 46 is spaced apart from cooling surface 34 by a distance or gap 47, such as about 1 to 3mm (.04 to .12in). Recessed window 46 includes an inner window 48, typically permanently or semi-permanently mounted to copper block 32 at exit aperture 44, and an outer window 50. Outer window 50 is removable secured in place by the use of an clip, not shown, or other suitable means. Windows 48, 50 are made of a suitable material, such as fused silica, although other materials, such as optical glasses, could also be used. By the use of inner and outer windows 48, 50, if outer window 50 is damaged, it can be easily replaced by the user. Accordingly, outer window 50 acts as a sacrificial window which if damaged, such as can occur through spalling as a result of bits of hair exploding when subjected to high power radiation, can be easily replaced.



Cooling surface 34 is cooled through the use of a coolant evaporator 52 housed within a blind bore 54 formed in copper block 32. The coolant, which may be of various commercially available types, commonly Freon® or other fluorinated hydrocarbons, is directed to evaporator 52 through a coolant liquid line 56 and is recycled back to a refrigerant compressor 62 (see Fig. 3) through a coolant vapor return line 58. Line 58 coaxially houses coolant liquid line 56, line 58 being housed within thermal insulation 60. Lines 56, 58 and insulation 60 pass through umbilical cable 28 to refrigerant compressor 62 associated with a control console 64. Alternatively, cooling surface 34 can be cooled by a thermoelectric, Peltier device instead of the coolant evaporator. This, currently preferred, embodiment of the cooling device is discussed below with reference to Figs. 8A-8D.

While it is desired to cool surface 34, such cooling can result in condensation on the surfaces of radiation source 36, in particular on the walls of chamber 38 and on recessed window 46. To help prevent this, a separation slot 66 is made between that portion copper block 32 used to cool surface 34 and that portion of the block used for radiation source 36. An electrical, typically resistive, heating element 68 is positioned along one wall of slot 66, the right wall as shown in Figs. 3A and 3B, while the other, left wall is covered with thermal insulation 70. Heating element 68 is connected to console 64 through a conductor 71 extending along umbilical cable 28. In lieu of resistive heating element 68, the hot side of a thermoelectric type of heating element, such as discussed below with reference to Figs. 8A-8D, could be used.

Laser hair removal treatments are designed to be effective and yet safe. That is, the treatment should cause thermal damage to hair tissue 20 but not substantial damage to surrounding tissue, such as blistering to the skin. To do so the energy per unit area (fluence) of the laser beam 74 at skin surface 6 must be controlled. Part of this control requires that the distance between skin surface 6 and the end of optical fiber 42 be controlled because beam 74 expands as it passes through reflective chamber 38. The distribution of energy across the laser beam at the skin surface should be substantially constant so that no hot spots, which could cause local damage to the epidermis, are created. Also, the individual exposure sites must fit tightly together, commonly called a tiled effect, so that there is little or no overlapping of the exposure sites and, at the same time, little or no area is left unexposed. The simplest shape that meets this tiling requirement is a rectangle. Other shapes can create a tiled pattern but they have other

drawbacks. Reflective chamber 38 and window 46 both have square cross-sectional shapes for efficient and effective treatment.

Fig. 5 illustrates a graph of fluence versus radial position for a diverging beam, such as from optical fiber 42. What is desired is to square off the graph to equalize the fluence over the beam spot. This is suggested in Fig. 5A in which those portions of the beam at the edges are reflected or folded over back into the main portion of the beam to create a generally square wave graph of fluence versus radial position. Fig. 6 illustrates how this is accomplished with the present invention. The walls 72 of chamber 38 are made to be highly reflective of the particular wavelength of radiation. In the preferred embodiment the wavelength is 1.06 micron and surface 72 is provided with a highly reflective gold surface. As suggested in Figs. 5A and 6, the diverging laser beam 74 not only passes directly through window 46 but the edge portions of the beam are reflected off the walls 72 back into the main portion of the beam to create a generally equalized fluence level. Other optical arrangements can be used to help equalize the fluence applied to skin surface 6. For example, various devices called optical integrators or beam homogenizers are well known in the art of laser material processing. The simplicity of the present device is possible because the exit aperture, by virtue of being close to the cooling surface 34, is located close to the target surface.

In another embodiment, shown in Fig. 9, reflective chamber 38, exit aperture 44 and protective window 46A are spaced much further from the skin surface to, for example, give the practitioner a better view of the treatment area 73 through a view port 75. View port 75 may be an open region, as illustrated, or it could include, for example, transparent and/or reflective members to permit direct or indirect viewing of area 73. In this case, a lens system 77 is used between exit aperture 44 and window 46A to make an image of the exit aperture on the skin surface at treatment area 73. With this approach, the size of the exit aperture need not be the same size as the treatment area 73 on the skin surface. The size of treatment area 73 could be made variable by proper selection of the focal length of lens system 77 and the distance between exit aperture 44 and the lens system. This would be useful when it is desired to use the device for other treatments, such as the treatment of varicose veins.

One way to control unwanted thermal damage to the skin is to cool the epidermis. Fig. 7 illustrates several idealized plots of tissue temperature versus depth below the skin surface. Plot A shows the normal variation of temperature versus depth

with the temperature rapidly approaching the normal core temperature of 37°C. Plot B illustrates the temperature at a range of tissue depth following a laser pulse when there has been no prior cooling of the skin. Assuming the energy is high enough to cause thermal damage at a depth of about 2 to 4mm, the typical range of depths need to cause damage to hair tissue 20, the skin surface temperature is hot enough to cause blistering and burning. The blistering and burning range is indicated by region 76, that is above about 68°C, while the temperature needed to cause hair tissue damage is indicated by region 78, that is above about 48°C. Plot C illustrates the result of cooling the skin surface after adequate pre-cooling. Adequate pre-cooling has commonly been found to be created when an copper heat sink, pre-cooled to about 0°C, is applied to the skin surface for about 1 to 2 seconds. Plot D plots temperature versus skin depth immediately after exposing the skin surface, pre-cooled as in the Plot C, to a laser-pulse similar to that which created Plot B. As can be seen, pre-cooling the skin surface results in prevention of burning or blistering the skin while permitting the target tissue, that is hair tissue 20, to be raised to a sufficiently high temperature to cause thermal damage to the tissue. Note that the plots in Fig. 7 are not taken from actual test data but are idealized plots provided to aid understanding the advantages of pre-cooling of the skin.

Several patents discuss surface cooling to prevent tissue damage. See, for example, U.S. Patents 5,057,104; 5,282,789 and 5, 735,844. Coherent of Santa Clara, California sells a diode laser system for dermatological use as the LightSheer. This product provides a hand piece with a cold window through which the laser exposure occurs. To use the device the window is first pressed against the treatment side for a period of time and then the laser beam is fired through the window. One of the problems with this simultaneous cooling technique when applied to laser hair removal is that it takes two to three seconds with the skin in contact with the cooled window to properly cool the skin surface to about 10 to 15°C. Thus, the practitioner must wait for about one to three seconds at each treatment site before firing the laser-pulse.

The present invention eliminates any need to wait prior to firing the laser-pulse by separating the cooling surface and the laser discharge window. As seen in Fig. 4, cooling surface 34 lies adjacent to window 46 in the direction of movement indicated by arrow 80. The width of surface 34 and window 46 are substantially the same while the length of 34 is about twice the length of window 46, that is with the length considered to be in the direction of arrow 80. Assuming a cooling time of two seconds is desired, the

forward end 82 of cooling surface 34 is placed over the first target area on skin surface 6. After about one second in that position, device 22 is moved in the direction of arrow 80 the length of recessed window 46; in the preferred embodiment this is about one centimeter. At this time the first target area shifts to a position covered by cooling  
5 surface 34 but adjacent to window 46. After a second one-second interval, device 22 is again moved the length of recessed window 46; at this time the first target area, which has been cooled for a total of about two seconds, is aligned with recessed window 46. The practitioner then presses a fire button 84 on body 24 of device 22 causing a laser-pulse to be directed at skin surface 6. The practitioner then continues moving device 22 and  
10 pressing fire button 84 at one-second intervals to provide the desired laser treatment of the skin surface.

The desired two-second cooling of skin surface 6 could also be done with cooling surface 34 about the same size as window 46. To do so would require that device 22 be moved only every two seconds, or some other length of time needed to cool the  
15 skin surface 4. By making cooling surface 34 with a length greater than the length of window 46, the amount of time between laser-pulses need not be controlled by how long it takes to cool the skin surface. Rather, the device can be designed so that the time between laser-pulses is chosen to be at a comfortable pace for the operator while not unduly extending the time the entire procedure takes. For example, if it is believed that  
20 the proper interval between pulses is three-quarters of a second but the skin area needs to be cooled for three seconds, the length of cooling surface 34 could be made to be about four times the length of window 46; using these parameters, moving device 22 by the length of window 46 between each pulse permits the skin surface to be cooled for the desired three seconds while the practitioner can operate the fire button at the desired  
25 three-quarter second between pulses. Therefore, the length of the cooling surface (Y) is equal to the length of the window (X) multiplied by the time desired to cool the target site (C), the result divided by the desired interval between laser pulses (Z); that is ,  $Y=(X \times C)/Z$ . Adjustments to the thermal capacity, thermal conductivity and temperature of block 30 and cooling surface 32 can also be made to vary the required time needed to  
30 cool skin surface 6.

Fig. 4A illustrates an alternative embodiment of the invention in which window 46A is rectangular having a width about three times its length. In this case cooling surface 34A would have a width about equal to the width window 46A.

However, the length of cooling surface 34A is, like in the embodiment of Fig 4, about twice the length of window 46A based on the premise that the interval between actuation of fire button 84 will be equal to one-half the length of time it is desired to apply equal surface 34A to the skin surface to properly cool the skin surface.

5                   The pre-cooling of the skin surface followed by the irradiation is based on the premise that the skin can be cooled relatively quickly compared with the time it takes to warm back to its normal temperature. For example, in one experimental trial using a cooling surface 34 maintained at about 0°C and applying the cooling surface to skin surface 6 for one second lowered the skin surface temperature about 12°C; application for  
10 two seconds lowered the skin temperature by about 18°C; application for three seconds lowered the skin temperature by about 20°C. Therefore, two seconds of cooling time appears to be adequate with this particular cooling surface; three seconds of cooling time is better but only marginally so. While one second of cooling time does produce a significant drop in skin temperature, it may not be adequate depending upon various  
15 factors, primarily the amount of pigment in the patient's skin, the patient's hair color and other such factors. Accordingly, it is believed cooling times from about one to two seconds, and generally more preferably about two seconds, are expected to produce good results at a reasonable pace with the disclosed embodiment.

                  In another mode of operation which could be used by experienced  
20 practitioners, the laser system would be set to emit pulses continuously at a constant repetition rate of, for example, 1 Hz. The practitioner would hold the handpiece in continuous contact with the patient's skin and move it at a constant velocity equal to the product of exposure-area length time repetition rate. This will maximize the rate at which the treatment proceeds while still providing adequate skin cooling and complete coverage.

25                   Figs. 8A-8D illustrate another alternative embodiment hair removal device 22 but with the ergonomically shaped body shown in Fig. 3 removed. Device 22A is similar to device 22 but instead of using coolant evaporator 52, device 22 uses a thermoelectric device 88, typically a Peltier device. Thermoelectric device 88 has a warm part 85 and a cold part 86 created by the passage of electricity through the thermoelectric device. To remove the heat created at warm part 85, thermoelectric device 88 includes a  
30 water cooled copper heat sink 90 having inlet and outlet lines 92, 94. The cold part 86 of device 88 is thermally coupled to copper block 32A by a bar extension 93 of block 32A so to cool cooling surface 34A, block 32A being gold-plated.

Fig. 10 illustrates another embodiment of the invention in which recessed window 46 is centered between two cooling surfaces 34. This provides two advantages: (1) the practitioner can move device 22 in either direction, back and forth, without having to rotate the handpiece, (2) the trailing cooling surface will reduce both pain and trauma to the skin following the laser exposure. This will be particularly important for the treatment of patients with darker skin types.

Fig. 11 illustrates a further embodiment of the invention similar to the embodiment of Figs. 8A-8D and also with the ergonomically shaped body shown in Fig. 3 removed. Reflective chamber 38B of hair removal device 22B includes a total internal reflecting optical element 100 having an entry surface 102 which accepts laser beam 74, an exit surface 104 facing recessed window 46, and a total internal reflecting sidewall surface 106. By partially filling gold-plated chamber 38B with optical element 100, typically a rectangular fused silica block, the same goal of uniform fluence can be achieved with much reduced optical absorption loss. The gold plating on wall 72B still remains important to maintain reflectivity as high as practical for light scattered back from the treated skin. Entry and exit surfaces 102, 104, windows 48, 50 and optical fiber 42 are preferably coated with thin dielectric layers to reduce reflection losses.

Fig. 12 illustrates a slightly modified version of the hair removal device 22B of Fig. 11. Hair removal device 22C has a moisture wicking element 108, typically made of a refractory material such as glass or ceramic fibers that will not be affected by the laser beam if element 108 happens to be struck directly or indirectly by the laser beam. Element 108 is wrapped around the distal end 110 of reflective chamber 38A adjacent to copper block 32A. Element 108 continues along copper block 32A and then up along the side of water cooled heat sink 90C. Water cooled heat sink 90C is warm enough so that condensation which may collect at or near distal end 110 of reflective chamber 38A can be wicked away and evaporated by the heat generated by thermoelectric device 88. Doing so will help keep optically sensitive areas dry and free of conservation. In addition, the evaporation of water will help cool heat sink 90C. It may be necessary or desirable to provide vents or other structure to help remove warm, moist air produced by evaporating moisture from element 108 at heat sink 90C.

One embodiment of the laser system can operate at average power output levels of up to 120 watts delivered to tissue. Under these conditions there is enough absorption of laser power in reflective chamber 38A that it is important to thermally

connect it to a heat sink. One choice would be to connect chamber 38A to the cold part 86 of the thermo-electric cooling assembly. The problem with this configuration is that when device 22C is not delivering laser energy at a high rate, reflective chamber 38A would become cold enough to condense water vapor out of the air and could collect liquid water on sensitive optical surfaces. A better choice of heat sinking chamber 38A is to thermally connect it to water-cooled heat sink 90C. The cooling water can be supplied from the same circulation system used to cool the laser itself; this water is typically cooled by a water-to-air heat exchanger (not shown). When so cooled the cooling water can never be colder than room temperature and is usually at least several degrees to a few tens of degrees C warmer than room temperature. This helps to ensure that the reflective chamber is always above the dew point and therefore incapable of condensing water out of the air.

Thermal coupling of heat sink 90C with chamber 38A is provided by an extension 112 of heat sink 90. Extension 112 passes through a cut-out in a circuit board 116 and contacts a proximal end 118 of reflective chamber 38A. See Figs. 12 and 13. A pair of set screws 120 are used to secure proximal end 118 to extension 112 for stability and to ensure good thermal contact. Heat sink 90 is typically made of copper and chamber 38A is typically made of aluminum so that heat sink 90 keeps chamber 38A warm enough to help prevent condensation on chamber 38A.

Another aspect of the invention relates to the control of the laser-pulse according to the diameter of shaft 4 of hair 2. Part of this selection is based on the belief that laser-pulse duration should be selected to match the thermal relaxation time of the targeted hair. For small diameter hair the pulse should be shorter while for larger diameter hair the pulse should be longer. This belief is used in conjunction with the belief that high peak powers should be avoided. Thus, it is preferred to use longer pulse durations with lower peak powers and to selectively adjust the duration according to the shaft diameter to minimize or eliminate damage to epidermis 10 while not sacrificing heat transfer to hair tissue 20. With this in mind, it is believed that a wavelength in the range of about 800 to 1200nm would be quite suitable for use with the present invention. For the preferred embodiment a wavelength of 1.06 micron has been chosen. The choice of a 1.06 micron laser is beneficial for many reasons. It permits treating of patient having darker pigmented skin than the shorter wavelength lasers commonly used. The 1.06 micron laser is relatively efficient, requires no special cooling and has the ability to create

high pulse energy (such as about 4000 watts in one preferred embodiment) in low duty cycle pulses without large power-consuming support systems. Further the 1.06 micron laser can use flash lamp excitation which can be engineered at a fraction of the cost of high peak power diode lasers.

5 Console 64 is provided with control panel 95 (see Fig. 3) having a number of inputs 96 to provide the desired user control. Inputs 96 include a laser-pulse duration input, which is chosen according to the hair shaft diameter. The laser-pulse duration pulse input could be selected in terms of actual or relative time duration or in terms of actual or relative hair shaft diameter thickness. In addition to the laser pulse duration  
10 (hair shaft diameter) input, control panel 96 also includes one or both of a laser-pulse amplitude input or a laser-pulse fluence input. Other inputs to permit other variables to be controlled can also be provided. Console 64 may also include a display 98 to provide the user with information, such as the temperature of cooling surface 34, optimal laser pulse actuation rate, laser-pulse duration selected, etc. In one preferred embodiment  
15 control panel 95 includes the following inputs: keyswitch to start the system and turn it off, standby and ready buttons to select the state of operation, controls to select fluence level, pulse width and repetition rate, and emergency-off button; and has the option of displaying the following information: laser and handpiece status (ready/not ready), laser emission indicator, and pulse counter.

20 In use, the operator first determines the general diameter of the hair to be removed from the patient. Then the laser-pulse duration is selected using the appropriate input 96. In one embodiment, typical hair shaft diameters of about 25 to 150 micrometers will result in laser-pulse durations of about 25 to 150 microseconds. The laser-pulse amplitude or laser-pulse fluence is also selected using an appropriate input 96. After  
25 ensuring that the temperature of cooling surface 34 has reached the desired operating temperature, the front end 82 of cooling surface 34 is placed on the initial target area on the patient's skin. To ensure full treatment of the entire area of the skin without missing areas or having excessive overlaps in area, the skin area may be temporarily marked with a set of lines or a grid to help guide device 22. Front end 82 of cooling surface 34 is then  
30 placed at a first target area on the patient's skin. Cooling surface 34 typically remains in place from about .25 to two seconds. In one preferred embodiment, cooling surface 34 remains in place for one second; after the first second, device 22 is moved in the direction of arrow 80 a distance equal to the length of window 46. After remaining at this position



for one second, the user again moves a distance equal to one window length. At this point the first target area has been cooled for the designed two seconds so the target area can be irradiated by pressing fire button 84 during the next one-second interval.

Following the firing of a laser and the expiration of the one-second interval, the operator  
5 again moves device 22 in the direction arrow 80 one window length and presses fire button 84 to irradiate skin surface 6 thus causing thermal damage to hair tissue 20. The thermal damage is intended to cause the hair root area to be denatured so that the hair does not grow back. This procedure continues over the entire treatment area.

Modification and variation can be made to the disclosed embodiments  
10 without departing from the subject of the invention as defined in the following claims. While the invention has been described primarily with reference to hair-treatment methods, it may also be useful for other dermatological application.

Any and all patents, patent applications and printed publications referred to above are incorporated by reference.

WHAT IS CLAIMED IS:

- 1                   1.       A hair removal device comprising:  
2                   a body having a skin-contacting end;  
3                   a skin-cooling element carried by the body and having a cooling surface at  
4 the skin-contacting end;  
5                   a radiation source carried by the body and having a recessed window  
6 through which hair tissue-damaging radiation passes to a patient's skin;  
7                   said recessed window being laterally offset from the cooling surface; and  
8                   said recessed window being spaced apart from the cooling surface in a  
9 direction away from the patient's skin when the cooling surface is contacting the patient's  
10 skin so to create a gap between the window and the patient's skin.
- 1                   2.       The device according to claim 1 further comprising a radiation  
2 pulse actuator button carried by the body.
- 1                   3.       The device according to claim 1 wherein said radiation source  
2 comprises an optical chamber having an exit aperture covered by said recessed window  
3 and an optical fiber entrance in which an optical fiber can be housed to permit hair tissue-  
4 damaging radiation to pass from the optical fiber into the optical chamber.
- 1                   4.       The device according to claim 3 wherein the exit aperture is  
2 rectangular.
- 1                   5.       The device according to claim 4 wherein the exit aperture is square.
- 1                   6.       The device according to claim 3 wherein the optical chamber  
2 comprises light-reflecting walls which help to equalize the fluence of radiation passing  
3 through the exit aperture.
- 1                   7.       The device according to claim 3 wherein said optical chamber  
2 comprises a total internal reflecting optical element having an entry surface facing the  
3 optical fiber, an exit surface facing the recessed window and a total internal reflecting  
4 sidewall surface so that effectively all radiation entering the entrance surface from the  
5 optical fiber passes through the exit surface.

1                   8.       The device according to claim 7 wherein the optical element  
2 comprises a rectangular fused silica block.

1                   9.       The device according to claim 3 wherein said optical chamber  
2 comprises a beam size-defining lens system by which the lateral size of the radiation  
3 beam passing through the recessed window can be controlled.

1                   10.      The device according to claim 3 further comprising a heating  
2 element thermally coupled to the optical chamber so to permit heating of at least a part of  
3 the optical chamber.

1                   11.      The device according to claim 10 further comprising a moisture-  
2 wicking element extending between a region cooled by the skin-cooling element and the  
3 heating element so that condensation at said region can be wicked away for evaporation  
4 by the heating element.

1                   12.      The device according to claim 1 wherein the cooling surface is  
2 adjacent to the recessed window and is aligned with the recessed window along a  
3 direction of motion.

1                   13.      The device according to claim 12 wherein the recessed window and  
2 the cooling surface have window and cooling surface dimensions along the direction of  
3 motion.

1                   14.      The device according to claim 13 wherein the cooling surface  
2 dimension is at least about two times the window dimension.

1                   15.      The device according to claim 13 wherein the cooling surface  
2 dimension is about equal to the window dimension multiplied by a first chosen time  
3 interval for cooling the patient's skin, the result divided by a second chosen time interval  
4 between applications of the hair tissue-damaging radiation.

1                   16.      The device according to claim 1 wherein the window comprises an  
2 inner window and an outer, user-replaceable window.

1                   17.     The device according to claim 15 further comprising an user-  
2 removable clip releasably mounting the outer window to the body adjacent to the inner  
3 window.

1                   18.     The device according to claim 1 wherein the body is a hand-  
2 grippable body.

1                   19.     The device according to claim 1 wherein the cooling surface is a  
2 high lubricity surface to help prevent bonding between the cooling surface and skin.

1                   20.     The device according to claim 1 further comprising a view port  
2 formed adjacent to the recessed window to permit viewing of the patient's skin directly  
3 under the recessed window.

1                   21.     The device according to claim 1 further comprising means for  
2 viewing of the patient's skin directly under the recessed window.

1                   22.     The device according to claim 1 wherein the skin cooling element  
2 comprises first and second of said cooling surfaces with the recessed window being  
3 located between said first and second cooling surfaces.

1                   23.     A hair removal assembly comprising:  
2                   a body having a skin-contacting end;  
3                   a skin-cooling element carried by the body and having a cooling surface at  
4 the skin-contacting end;  
5                   a radiation source carried by the body and having a window through which  
6 hair tissue-damaging radiation passes to a patient's skin;  
7                   said window being laterally offset from the cooling surface;  
8                   a laser supplying laser light to the radiation source for passage through the  
9 window; and  
10                  laser-power inputs comprising a laser-pulse duration input and one of a  
11 laser-pulse amplitude input and a laser-pulse fluence input.

1                   24.     The assembly according to claim 23 wherein said window is a  
2 recessed window spaced apart from the cooling surface in a direction away from the

3 patient's skin when the cooling surface is contacting the patient's skin so to create a gap  
4 between the radiation source and the patient's skin.

1                   25.     The assembly according to claim 23 further comprising a source of  
2 a liquid coolant, and wherein the cooling element comprises a heat sink, a coolant  
3 evaporator thermally coupled to the heat sink, a coolant supply line coupling the coolant  
4 evaporator to the source of liquid coolant, and a coolant vapor return line coupling the  
5 evaporator to the source of liquid coolant.

1                   26.     The assembly according to claim 25 wherein the source of liquid  
2 coolant comprises a refrigerant compressor.

1                   27.     The assembly according to claim 23 wherein the skin-cooling  
2 element comprises a heat sink and a thermoelectric device having a cooled part, thermally  
3 coupled to the heat sink, and a heated part.

1                   28.     The assembly according to claim 27 wherein the heated part of the  
2 thermoelectric device is thermally coupled to a second heat sink.

1                   29.     The assembly according to claim 28 wherein the second heat sink  
2 is a liquid-cooled heat sink.

1                   30.     The assembly according to claim 23 further comprising a heating  
2 element thermally coupled to the radiation source.

1                   31.     The assembly according to claim 30 further comprising a moisture-  
2 wicking element extending between a region cooled by the skin-cooling element and the  
3 heating element so that condensation at said region can be wicked away for evaporation  
4 by the heating element.

1                   32.     The assembly according to claim 31 wherein the heating element  
2 comprises a heat sink portion and said wicking element is in contact with the heat sink  
3 portion of the heating element.

1                   33.     The assembly according to claim 23 wherein said radiation source  
2 comprises an optical chamber having an exit aperture covered by said window and an

3 optical fiber entrance in which an optical fiber is housed to permit laser light from the  
4 laser to be directed into the optical chamber, and further comprising a heating element  
5 thermally coupled to the optical chamber to help prevent condensation on said optical  
6 chamber or said window.

1 34. The assembly according to claim 33 wherein the heating element  
2 comprises a heat sink portion in physical contact with the optical chamber.

1 35. The assembly according to claim 26 wherein said optical chamber  
2 comprises a total internal reflecting optical element having an entry surface facing the  
3 optical fiber, an exit surface facing the recessed window and a total internal reflecting  
4 sidewall surface so that effectively all radiation entering the entrance surface from the  
5 optical fiber passes through the exit surface.

1 36. The assembly according to claim 35 wherein the optical element  
2 comprises a rectangular fused silica block.

1 37. The assembly according to claim 26 wherein said optical chamber  
2 comprises a beam size-defining lens system by which the lateral size of the radiation  
3 beam passing through the recessed window can be controlled.

1 38. The assembly according to claim 26 further comprising a moisture  
2 wicking element extending between a region cooled by the skin-cooling element and the  
3 heating element so that condensation at said region can be wicked away for evaporation  
4 by the heating element.

1 39. A hair-removal method comprising:  
2 determining the diameter typical of the hair to be removed from a patient;  
3 selecting a laser-pulse duration for a hair removal device according to this  
4 diameter of the hair so that smaller diameter hair results in a shorter laser-pulse duration  
5 than larger diameter hair; and  
6 applying laser energy through a window of the hair removal device of the  
7 selected laser-pulse duration to a patient's skin to cause thermal injury to hair tissue.

1 40. A method for preparing a hair-removal device for use comprising:

2                   determining the diameter typical of the hair to be removed from a patient;  
3    and  
4                   selecting a laser-pulse duration for a hair removal device according to this  
5    diameter of the hair so that smaller diameter hair results in a shorter laser-pulse duration  
6    than larger diameter hair.

1                   41.    The method according to claims 39 or 40 further comprising the  
2    step of selecting a chosen one of a laser-pulse amplitude and a laser-pulse fluence prior to  
3    the applying step.

1                   42.    The method according to claim 39 wherein the laser energy  
2    applying step is carried out by:  
3                   positioning a cooling element of the hair removal device against a first  
4    target area on the patient's skin;  
5                   moving, after a chosen cooling period of time, the cooling element from  
6    the first target area to a second target area with the window overlying and spaced-apart  
7    from the first target area;

8                   applying the laser energy to the first target area through the window with  
9    the window overlying and spaced-apart from the first target area

1                   43.    The method according to claim 42 further comprising moving, after  
2    the laser energy applying step, the window to overlay the second target area while  
3    positioning a second cooling surface against the first target area.

1                   44.    The method according to claim 42 wherein the moving step is  
2    carried out with the chosen cooling period of time being about .25 to two seconds.

1                   45.    The method according to claims 39 or 40 further comprising the  
2    step of selecting a hair removal device using laser energy in the 800 to 1200nm wavelength  
3    range.

1                   46.    The method according to claims 39 or 40 further comprising the  
2    step of selecting a hair removal device using laser energy having a wavelength of about  
3    1.06 microns.

1                   47.     The method according to claims 39 or 40 wherein the selecting step  
2     is carried out so that hair diameters from about 25 to 150 micrometers result in laser-pulse  
3     durations of about 5 to 50 milliseconds.

1                   48.     A method for preparing to apply hair tissue-damaging radiation to a  
2     target site on a patient's skin comprising:

3                   accessing a hair removal device having a skin cooling surface and a  
4     radiation source with a window through which hair tissue-damaging radiation passes, the  
5     skin cooling surface and the window aligned along a direction of motion;

6                   selecting a chosen one of :

7                   (i) a first chosen time interval (C) for cooling the target site; and

8                   (ii) a second chosen time interval (Z) between applications of hair  
9     tissue-damaging radiation; and

10                  determining the other of the first and second time intervals based on the  
11     following:

12                    $Y = (X \times C) / Z$ , where

13                   X and Y are the respective lengths of the cooling surface and the  
14     window measured in the direction of motion.



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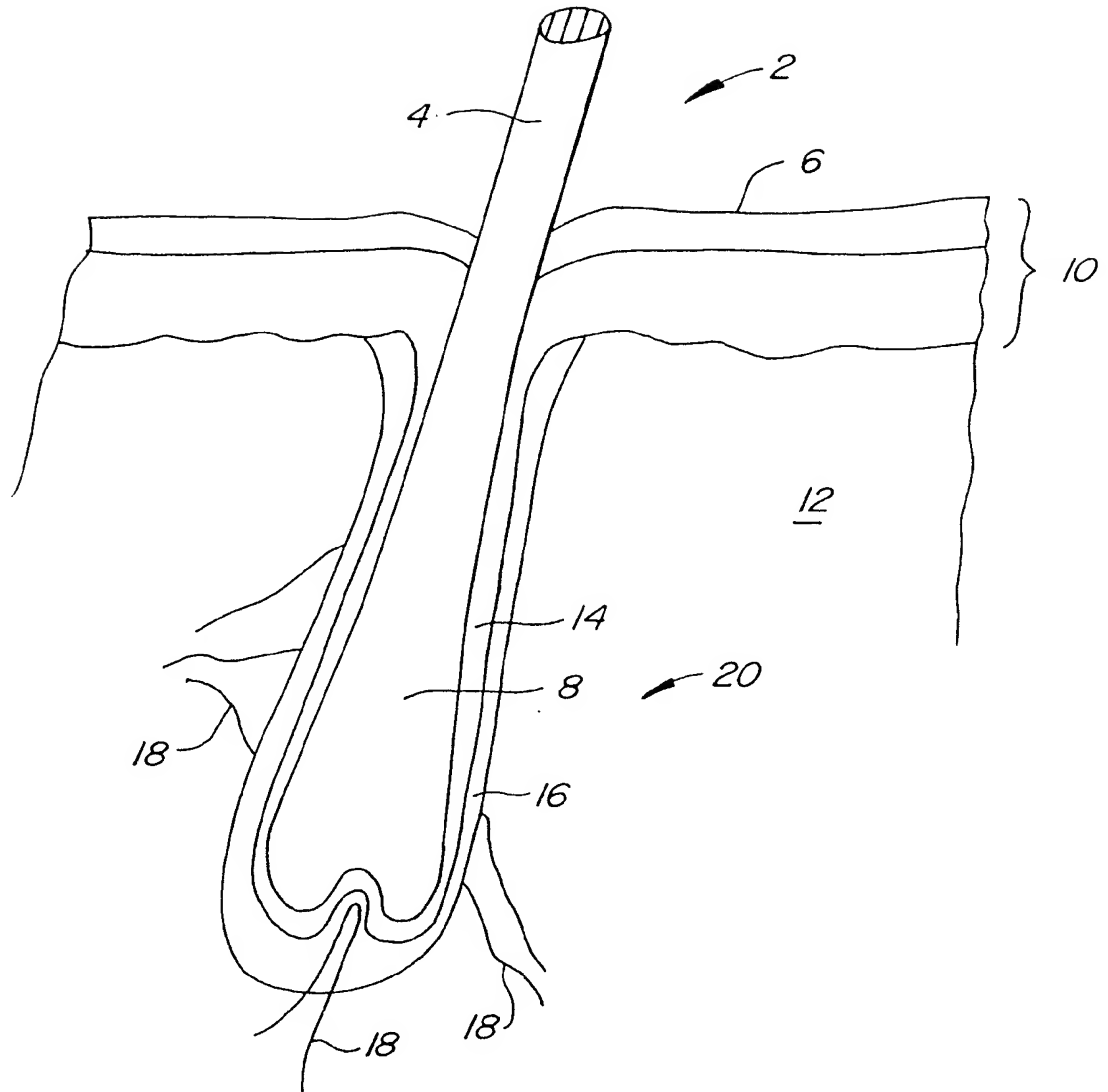


FIG. 1.

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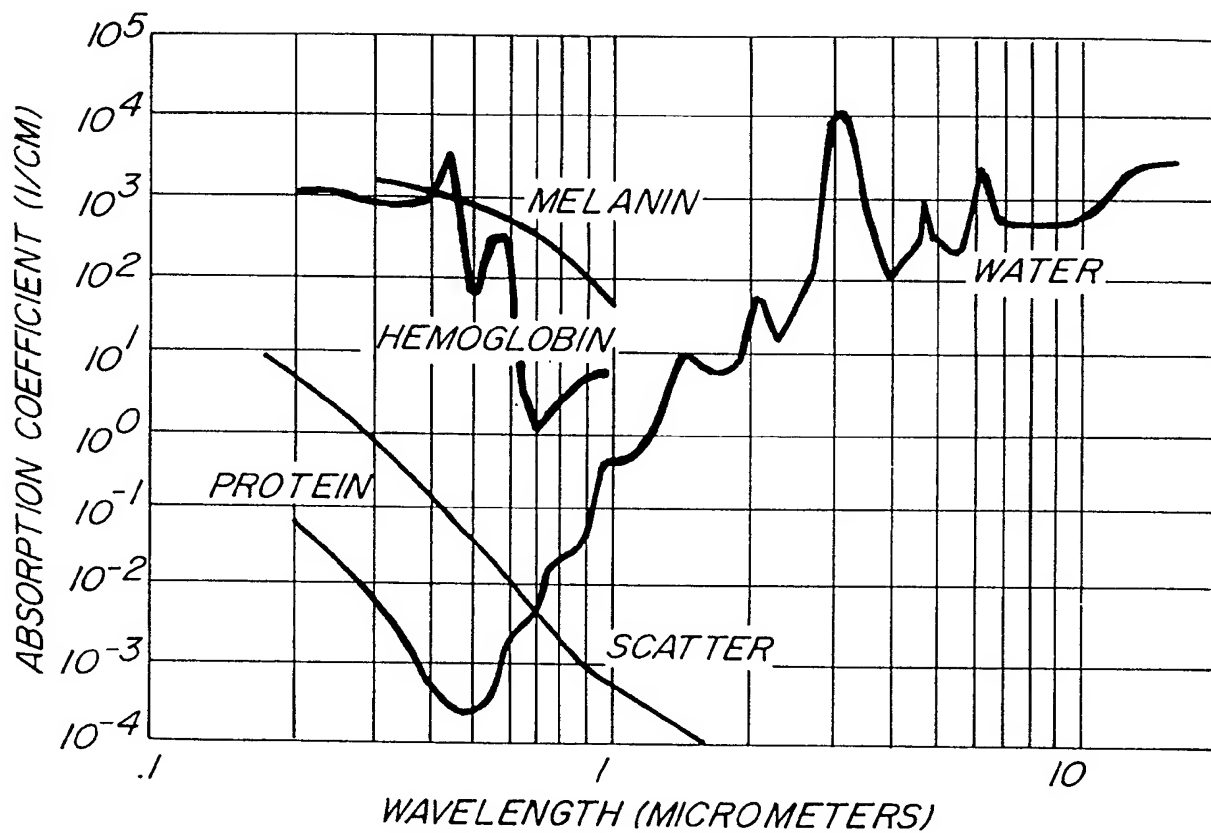


FIG. 2.

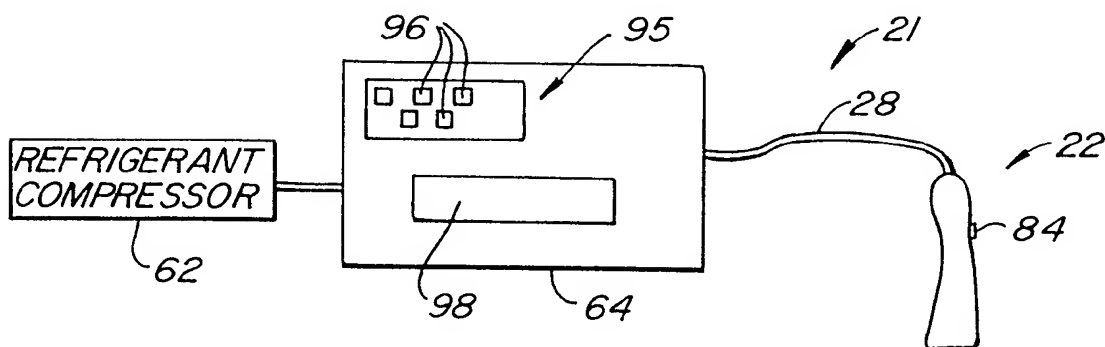


FIG. 3.

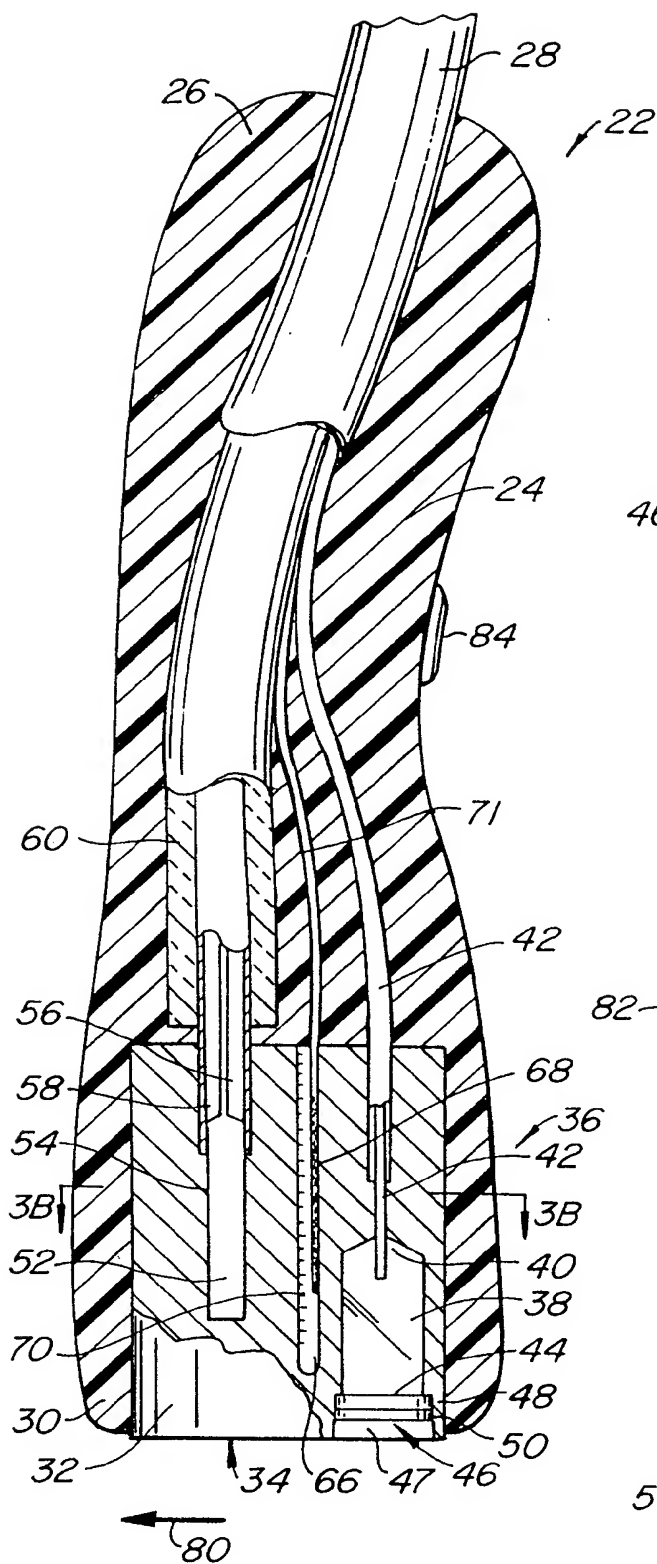


FIG. 3A.

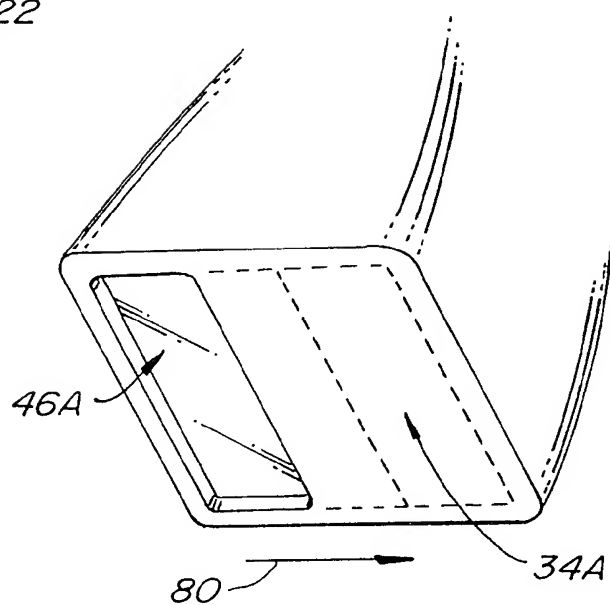


FIG. 4A.

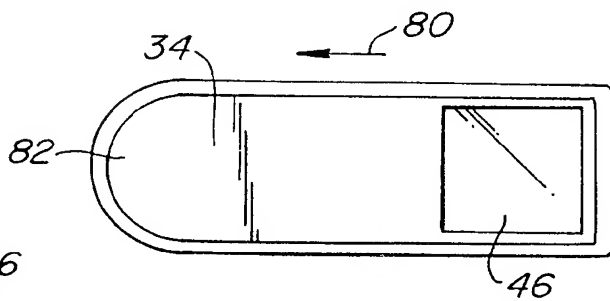


FIG. 4.

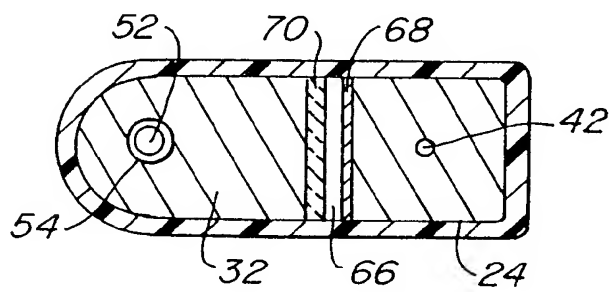


FIG. 3B.

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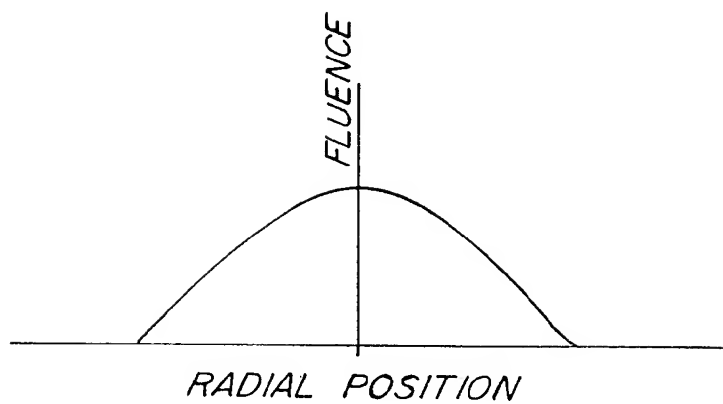


FIG. 5.

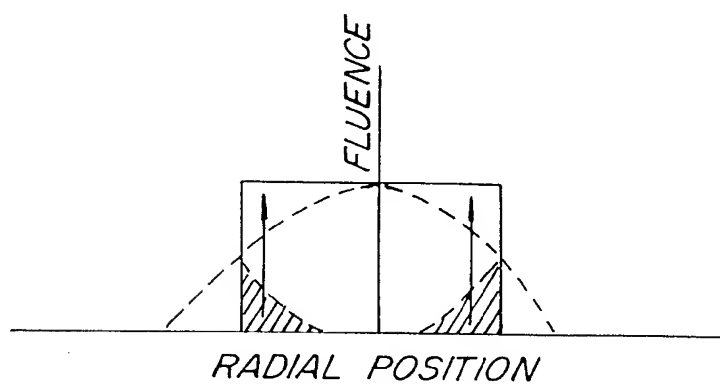


FIG. 5A.

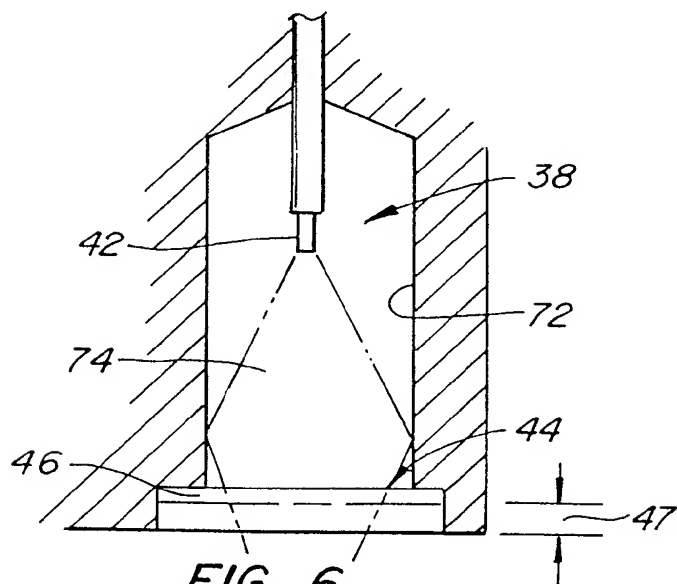


FIG. 6.

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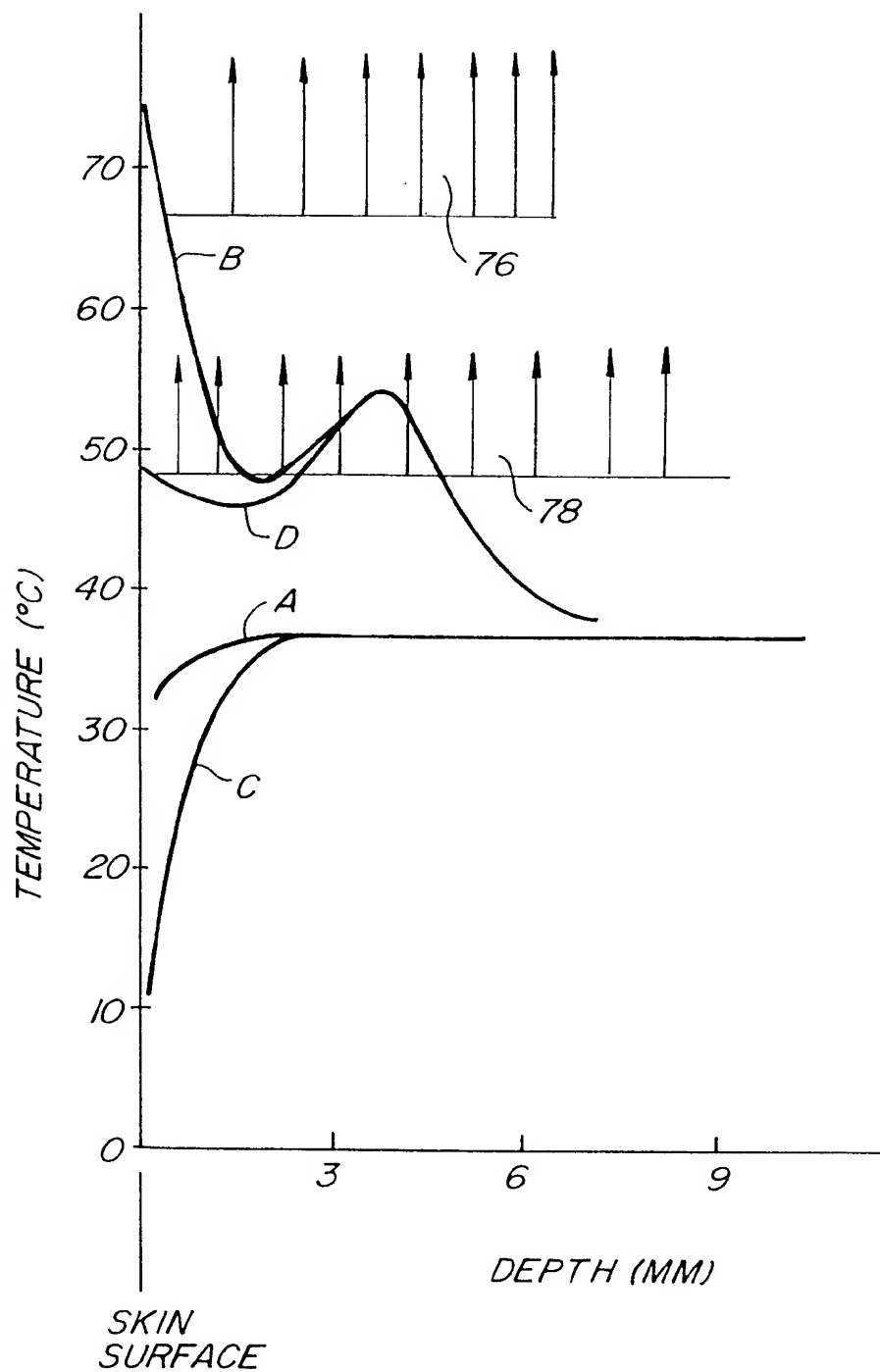


FIG. 7.

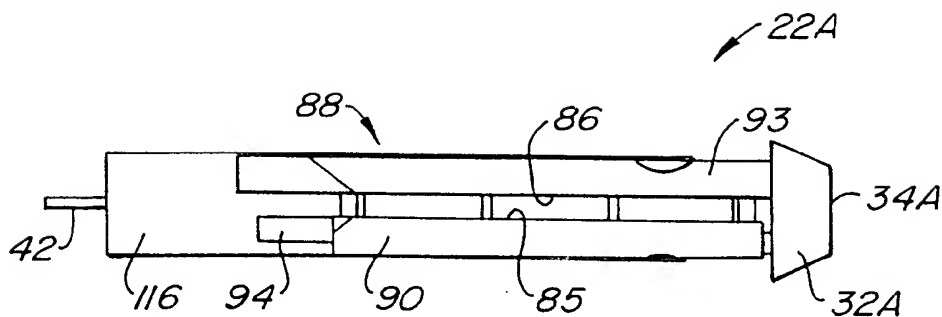


FIG. 8C.

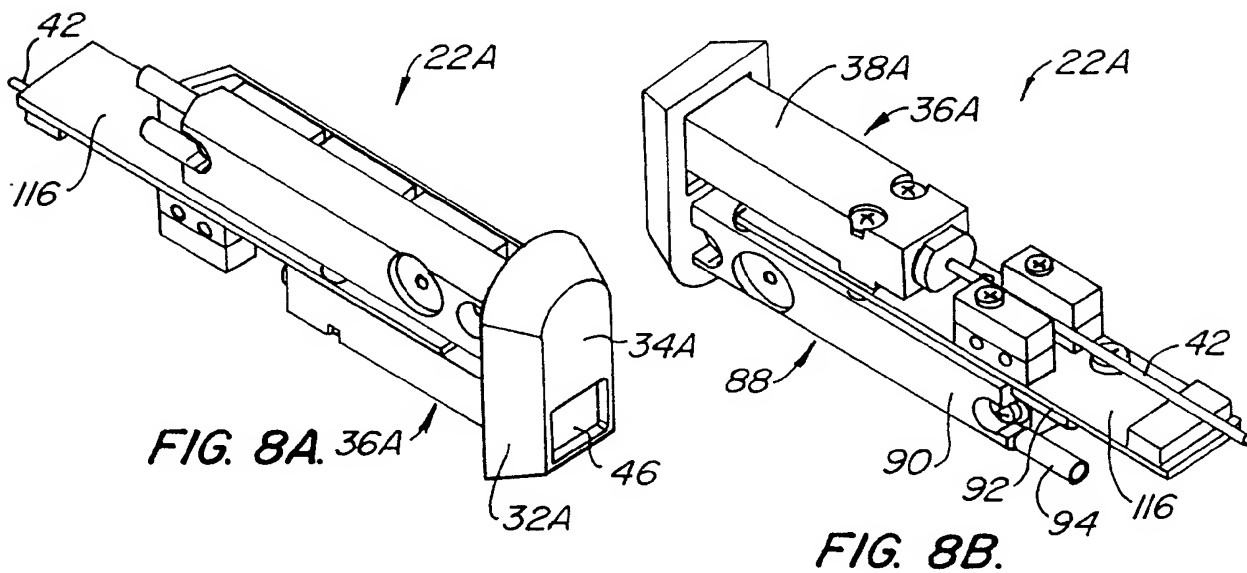


FIG. 8A.

FIG. 8B.

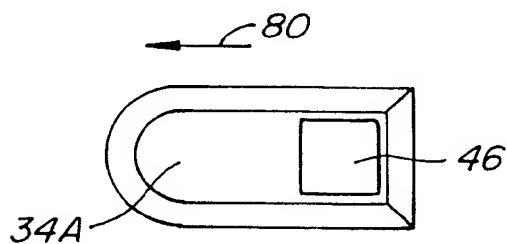


FIG. 8D.

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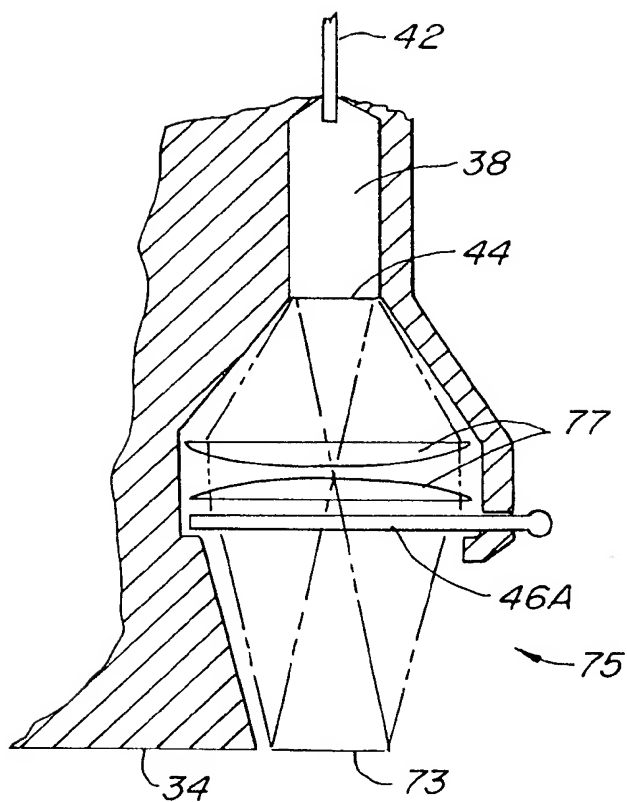


FIG. 9.

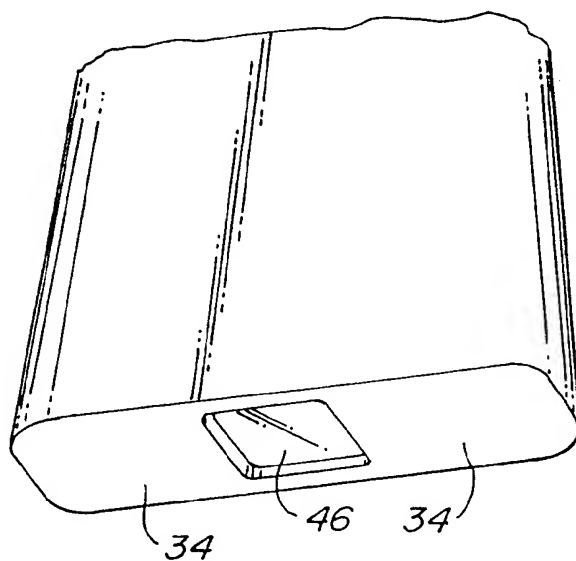


FIG. 10.

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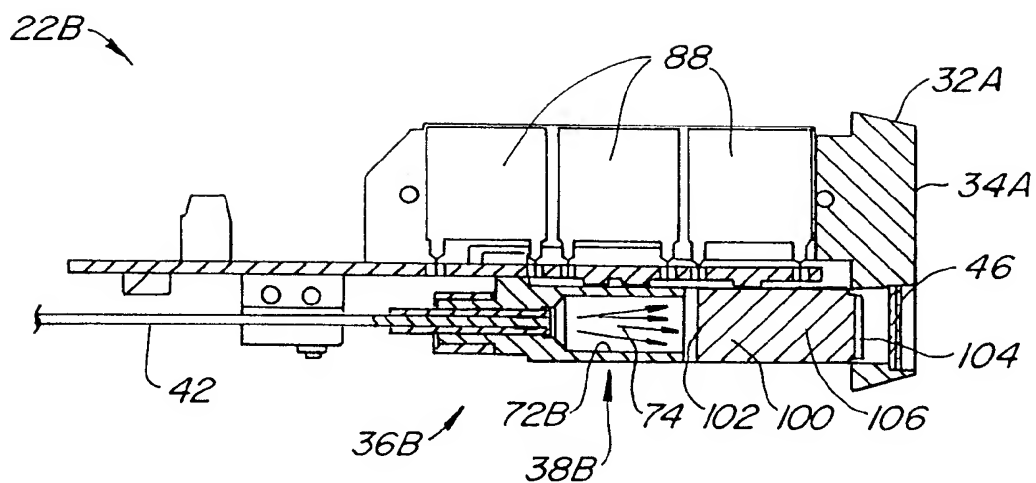


FIG. 11.

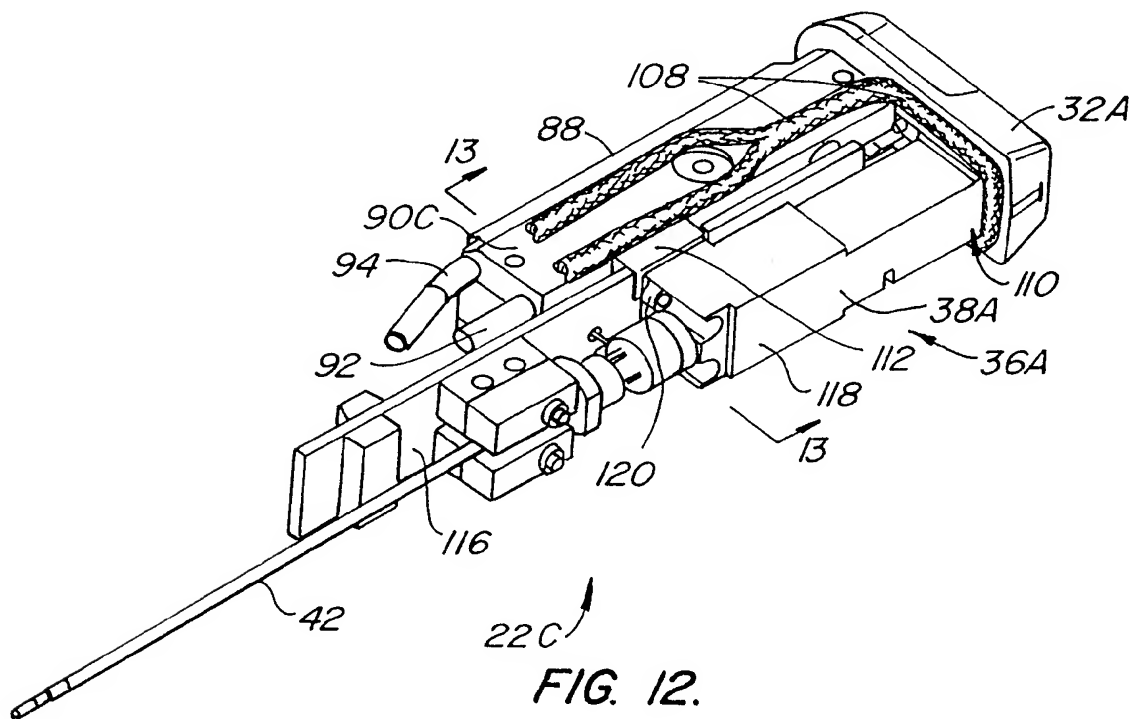


FIG. 12.

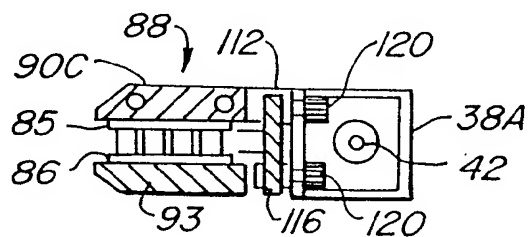


FIG. 13.



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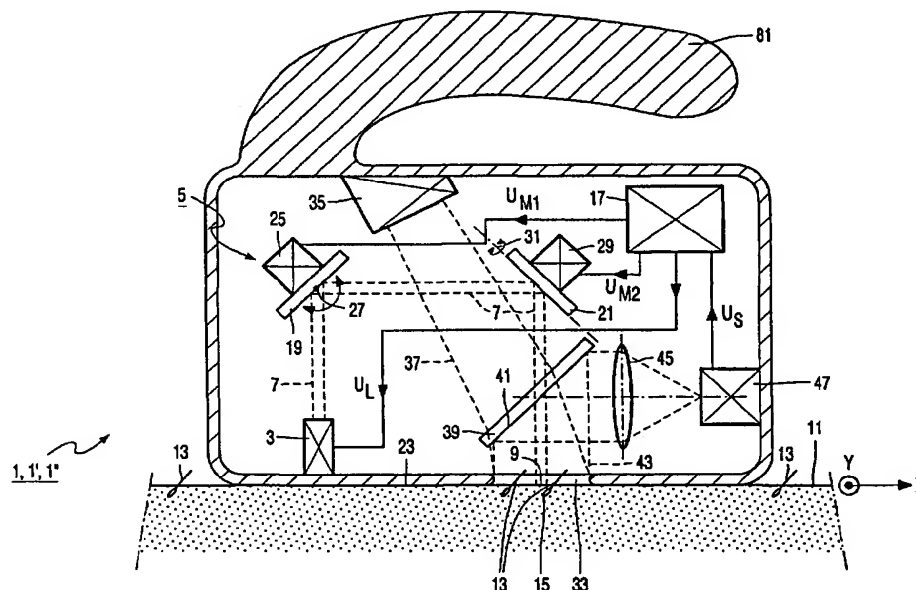
(51) International Patent Classification <sup>7</sup> : A61B 18/20	A1	(11) International Publication Number: WO 00/62700 (43) International Publication Date: 26 October 2000 (26.10.00)
(21) International Application Number: PCT/EP00/02871 (22) International Filing Date: 3 April 2000 (03.04.00) (30) Priority Data: 99201169.2 14 April 1999 (14.04.99) EP (71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL). (72) Inventors: LEFKI, Karim, M., T.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). CENSE, Abraham, J.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). CHENG, Xiang, S.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN AMSTEL, Willem, D.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VELDHUIS, Gerrit, J.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). (74) Agent: WOLFS, Marc, J., M.; Internationaal Octrooibureau B.V., Prof Holstlaan 6, NL-5656 AA Eindhoven (NL).		(81) Designated States: IL, JP, MX, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

(54) Title: HAIR-REMOVING DEVICE WITH A CONTROLLABLE LASER SOURCE

## (57) Abstract

A hair-removing device (1) comprises a laser source (3), an adjustable laser beam manipulator (5) for positioning a laser beam (7) of the laser source (3) in a target position (9) on a skin (11) to be treated, and an image sensor (47) for detecting an image (49) of the skin. According to the invention, the hair-removing device further comprises a control unit (17) which determines a position and orientation on the skin of a hair (13) to be removed, and which determines the target position of the laser beam as a function of said position and orientation of the hair. The control unit brings the laser beam manipulator in a state corresponding to the target position of the laser beam, and activates the laser source when the laser beam manipulator has reached said state. Thus, the hair-removing device is suitable for use by inexperienced users, and is particularly suitable for the consumer market.

In a particular embodiment, the control unit determines the target position of the laser beam in a position (71) on the skin under which a root (15) of the hair is present, so that the root of the hair is destroyed and the hair-removing device (1) is an epilating device by means of which the hair is removed for a relatively long time or even permanently. In another embodiment, the control unit determines the target position of the laser beam in a position (65) on the hair where the hair comes out of the skin, so that the hair is burnt through near the skin surface and the hair-removing device (1'') is a shaving device by means of which a high skin smoothness is obtained.



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Hair-removing device with a controllable laser source.

The invention relates to a hair-removing device provided with a laser source, an adjustable laser beam manipulator for positioning a laser beam supplied by the laser source during operation in a target position on a skin to be treated, and an image sensor for detecting an image of at least a portion of the skin.

5

A hair-removing device of the kind mentioned in the opening paragraph is known from US patent 5,653,706. The known hair-removing device is designed for use by a professional therapist and may be used not only for removing hairs but also for other dermatological treatments such as the treatment of necrotic skin tissue, varicose veins, or pigment spots. The image of the skin detected by the image sensor is rendered visible to the therapist on a picture screen. The known hair-removing device further comprises a control member by means of which the therapist can operate the laser beam manipulator and can thus guide the laser beam supplied by the laser source manually over the skin under treatment. While being guided over the skin, the laser beam has only a comparatively low energy density, and the therapist can monitor the position of the laser beam on the skin by means of the picture screen. When the laser beam is in the target position as determined by the therapist, the laser beam can be intensified for a predetermined time duration by the therapist through the operation of a further control member of the hair-removing device. The laser beam has a wavelength which is well absorbed by the tissue to be treated, so that the tissue present around the target position is strongly heated locally by the laser beam, and the relevant tissue dies. For a permanent removal or epilation of a hair present on the skin, the laser beam is aimed at the root of the hair, so that the root and the tissue surrounding it die. Since the known hair-removing device is provided with said image sensor and adjustable laser beam manipulator, it is possible to treat the skin locally with a laser beam of a comparatively small spot diameter, so that the laser source need have only a comparatively low power. Accordingly, a comparatively small and simple laser diode is used in the known hair-removing device.

20  
25

A disadvantage of the known hair-removing device is that a comparatively long treatment time is necessary for the removal of all hairs present on a skin under treatment because the therapist must displace the laser beam manually from one hair to the next. In

addition, a determination of the target position of the laser beam on the skin requires the user to have a considerable experience, so that the known hair-removing device is suitable exclusively for use by a professional therapist.

5           It is an object of the invention to provide a hair-removing device of the kind mentioned in the opening paragraph with which a comparatively short treatment time is possible and which is suitable for use by inexperienced persons, i.e. suitable for the consumer market.

10           To achieve this object, a hair-removing device according to the invention is characterized in that the laser source is controllable by means of an electrical control unit, which control unit during operation determines the target position of the laser beam as a function of a position and/or orientation on the skin of a hair to be removed as determined from the image by the control unit, and which control unit activates the laser source the moment the laser beam manipulator is in a position which corresponds to the target position of the laser beam. The determination of the target position of the laser beam and the activation of the laser source take place fully automatically because the target position of the laser beam is determined by the control unit and the laser source is activated by the control unit when the laser beam manipulator is in a position which corresponds to the target position of the laser beam. The control unit also renders it possible, for example, to adjust the laser beam manipulator in a predetermined manner automatically in that position which corresponds to the target position of the laser beam on the skin. This renders the hair-removing device according to the invention suitable for a safe use by inexperienced persons, so that the hair-removing device is particularly suitable for the consumer market. The control unit comprises, for example, a suitable algorithm for determining the target position for the laser beam from the image of the skin detected by the image sensor, which algorithm is capable of determining the position and/or the orientation of the hair to be removed on the skin on the basis of the image information and is capable of determining the target position on the basis of said position and/or orientation of the hair. The automatic determination of the target position of the laser beam as described above, the automatic adjustment of the laser beam manipulator, and the automatic activation of the laser source take place within a comparatively short time, so that a comparatively short treatment period can be achieved by means of the hair-removing device according to the invention.

          A special embodiment of a hair-removing device according to the invention is characterized in that the control unit determines the target position of the laser beam in a

partial region of the image having dimensions which are determined by a previously determined average distance between hairs present on the skin and a previously determined length of the hairs. In this special embodiment, the control unit is active substantially exclusively in said partial region of the image which comprises no more than a few hairs to be removed, and preferably only a single hair. Said previously determined length of the hairs should preferably be smaller than said average distance between the hairs and can be achieved, for example, in that the hairs are trimmed by means of a separate trimmer or, for example, a trimmer belonging to the hair-removing device prior to the treatment by means of the hair-removing device. Since the control unit is active substantially exclusively in said partial region of the image, a calculation time and calculation capacity of the control unit required for determining the target position are strongly reduced.

A further embodiment of a hair-removing device according to the invention is characterized in that the dimensions of the partial region of the image are adjustable. Since the dimensions of the partial region of the image are adjustable, said dimensions can be adapted to the properties of the skin under treatment by the user of the hair-removing device, so that the treatment time and treatment result can be optimized for each individual user.

A yet further embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a regular sequence of virtual positions of the laser beam on said portion of the skin, a reference position in the partial region of the image corresponding to the instantaneous virtual position of the laser beam, and the control unit activating the laser source when the reference position corresponds to the target position of the laser beam. In this yet further embodiment, the portion of the skin corresponding to the image is scanned by the laser beam manipulator in a regular manner.

Since the reference position lying in the partial region of the image corresponds to the instantaneous virtual position of the laser beam, the partial region of the image will follow the instantaneous virtual position of the laser beam, so that the target position in the partial region of the image as determined by the control unit changes continually with respect to the reference position. An advantage of this yet further embodiment is that the laser beam manipulator is continuously justed in a regular manner by the control unit, so that the laser beam manipulator need not have an exceptionally short adjustment time and an exceptionally high adjustment accuracy.

A special embodiment of a hair-removing device according to the invention is characterized in that the control unit determines the target position of the laser beam in a

regular sequence of consecutive partial regions of the image, the laser beam manipulator being adjustable by means of the control unit in each of said partial regions into a position which corresponds to the target position of the laser beam in the relevant partial region. In this special embodiment, the detected image of the skin is scanned by the control unit in a regular manner in accordance with said sequence of consecutive partial regions. The control unit determines a target position in each of the consecutive partial regions, whereupon the laser beam manipulator is adjusted into the position corresponding to the relevant target position by the control unit. An advantage of this special embodiment is that the laser beam manipulator need not scan the full portion of the skin which corresponds to the image but is merely adjusted consecutively into positions which correspond to the target positions as determined in the consecutive partial regions of the image. It is true that the laser beam manipulator is adjusted in an irregular manner by the control unit here, so that comparatively high requirements are imposed on the adjustment time and the adjustment accuracy of the laser beam manipulator, but the treatment time of the hair-removing device is considerably further reduced.

A further embodiment of a hair-removing device according to the invention is characterized in that the control unit determines from the position and orientation on the skin of the hair to be removed, as determined from the image, a region on the skin below which a root of the hair will be present with a predetermined degree of probability, the control unit determining at least one target position on the skin in said region. In this further embodiment, the hair-removing device is used as an epilation device. Since the laser beam treats the root of the hair, the root of the hair will die, as will the skin tissue present in the immediate vicinity, so that the hair is permanently removed, or at least for a longer period. The region on the skin below which the root is deemed to be present with the predetermined degree of probability is determined by the control unit on the basis of, for example, previously determined statistical information on the length of the subcutaneous portions of hairs and on the angle of the subcutaneous portions of hairs with respect to the skin surface.

A yet further embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a displacement of the laser beam over a rectilinear path on the skin with a predetermined velocity, said rectilinear path lying on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source at the start of said displacement. The region on the skin mentioned above below which the root of the hair will be

present with the predetermined degree of probability can thus be efficiently treated in its entirety, while a required spot diameter of the laser beam is considerably reduced.

A particular embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit  
5 into a number of consecutive fixed positions corresponding to a number of fixed target positions of the laser beam on a rectilinear path on the skin, which rectilinear path lies on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source in each of said fixed positions of the laser beam manipulator during a predetermined time. Said region on the skin  
10 below which the root of the hair will be present with the predetermined degree of probability can thus likewise be efficiently treated in its entirety, while a required spot diameter of the laser beam is likewise strongly reduced.

A further embodiment of a hair-removing device according to the invention is characterized in that the control unit determines an exit position on the hair, where the hair  
15 issues from the skin, from the position and orientation on the skin of the hair to be removed as determined from the image, the control unit equalizing the target position of the laser beam with a position on the hair adjacent said exit position. This further embodiment of the hair-removing device is used as a shaver. Since the target position of the laser beam lies on the hair adjacent the exit position of the hair, the hair will be burnt through by the laser beam adjacent  
20 the exit position, i.e. adjacent the skin surface. The control unit may be programmed, for example, such that the target position lies at a level with the skin surface, or even below the skin surface, so that a very smooth shaving result is obtained which is maintained for a comparatively long period. The hair-removing device may be provided, for example, with a further adjustment member for adjusting the target position relative to the skin surface, so that  
25 the user can set a desired smoothness.

A still further embodiment of a hair-removing device according to the invention is characterized in that the hair-removing device comprises a separate illumination member for illuminating at least the portion of the skin which is to be detected by the image sensor. The use of the separate illumination member achieves that the image detected by the image sensor  
30 is fully formed by light from the illumination member reflected by the skin, and the laser source can be completely switched off between the exposures of two consecutive target positions. Reflected light coming from the laser beam need not reach the image sensor because the image detected by the image sensor is fully formed by light of the illumination member reflected by the skin. Accordingly, the image sensor may be provided with a filter for the

reflected light of the laser beam, so that the image sensor is protected against damage which may arise as a result of the reflected light of the laser beam when the laser beam is in its target position and has a high energy density.

5 A special embodiment of a hair-removing device according to the invention is characterized in that the control unit determines from the image a reflection spectrum of the skin portion detected by the image sensor, the control unit comparing the reflection spectrum with a predetermined reference spectrum of at least one frequently occurring skin deviation, while the control unit determines from said comparison positions on the skin in which said skin deviation is present and does not activate the laser source in said positions on the skin. It is prevented in this special embodiment that the laser beam is aimed at target positions which lie within such a skin deviation such as, for example, a mole or some other pigment spot. Such skin deviations often have a comparatively high absorption power for the laser light used for the treatment of the hairs or hair roots, so that injuries arise in the case of contact with laser light. This special embodiment thus provides an automatic protection from such injuries.

15 A further embodiment of a hair-removing device according to the invention is characterized in that the control unit comprises means for determining an actual position of the laser beam on the skin from the image detected by the image sensor. Since the actual position of the laser beam on the skin is determined, the laser beam manipulator can, for example, be corrected or calibrated in such a manner that said actual position accurately corresponds with the desired target position determined by the control unit. Since said actual position is determined by the image sensor, a separate sensor for determining said actual position is not necessary, and the image sensor is used in an effective manner.

25 A yet further embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit via an output signal of the control unit in accordance with a predetermined mathematical relation between said output signal and the target position, the control unit comprising a calibration member for calibrating said predetermined mathematical relation on the basis of a measured relation between said output signal and the actual position of the laser beam on the skin. Since the control unit adjusts the laser beam manipulator in accordance with said predetermined mathematical relation between said output signal and the target position, the output signal required to achieve a predetermined target position can be determined by the control unit in a relatively short time period, so that the predetermined target position is achieved in a relatively short time period. Since said mathematical relation is calibrated on the basis of a measured relation between said output signal and said actual position, the laser beam



is very accurately positionable in the target position by the laser beam manipulator, so that damage of the skin around the target position by the laser beam is prevented as much as possible, and the target position is not missed by the laser beam.

A particular embodiment of a hair-removing device according to the invention is characterized in that, for determining the actual position of the laser beam on the skin, the control unit activates the laser source at a comparatively low energy density. When the laser source is activated at a low energy density, the laser beam generates a spot on the skin which is sufficiently bright to be detected by the image sensor, but which does not damage nor irritate the skin. Thus, the actual position of the laser beam on the skin can be determined by the control member of the control unit in a safe and reliable manner, and the energy consumption of the laser source is considerably limited.

The invention will be explained in more detail below with reference to the drawing, in which

Fig. 1 diagrammatically shows a hair-removing device according to the invention,

Fig. 2 is a diagrammatic cross-section of a skin to be treated adjacent a hair which is to be removed by means of the hair-removing device of Fig. 1,

Fig. 3 diagrammatically shows an image of a portion of a skin under treatment which is detected by means of an image sensor of the hair-removing device of Fig. 1,

Fig. 4 diagrammatically shows a control unit of the hair-removing device of Fig. 1,

Fig. 5a diagrammatically shows a partial region of the image of Fig. 3,

Fig. 5b diagrammatically shows a partial region of the image of Fig. 3 in an alternative embodiment of a hair-removing device according to the invention,

Fig. 6 shows a reflection spectrum determined by the control unit of Fig. 4 from the image of Fig. 3,

Fig. 7 diagrammatically shows a control unit of a further embodiment of a hair-removing device according to the invention,

Fig. 8 diagrammatically shows a partial region of a detected image of the skin under treatment generated by the control unit of Fig. 7, and

Fig. 9 diagrammatically shows a partial region of an image of the skin under treatment generated by a control unit of a yet further embodiment of a hair-removing device according to the invention.

The hair-removing device 1 according to the invention diagrammatically shown in Fig. 1 comprises a laser source 3 and an adjustable laser beam manipulator 5 for positioning a laser beam 7 supplied during operation by the laser source 3 in a target position 9 on a skin 11 to be treated. The hair-removing device 1 is an epilation device by means of which hairs 13 present on the skin 11 can be removed for a comparatively long period or even permanently. If a hair 13 is to be epilated, the target position 9 of the laser beam 7 must be approximately in a position on the skin 11 below which a root 15 of the hair 13 is present, as is diagrammatically shown in Fig. 2. The laser beam 7 contains monochromatic light with a wavelength which is well absorbed by the hair 13 and is substantially not absorbed by tissue of the skin 11. The result of this is that it is substantially exclusively the root 15 of the hair 13 which is strongly heated by the laser beam 7, so that the root 15 dies. A good optical selectivity between the hairs 13 and the tissue of the skin 11 is achieved with a wavelength between approximately 650 nm and 1200 nm in the case of a white skin with dark hairs. Light with such a wavelength is well absorbed by melanin, a pigment which occurs in a high concentration in dark hairs and only in a low concentration in a white skin. Light with such a wavelength is also badly absorbed by water, by hemoglobin, a red pigment which occurs in a high concentration in blood, and by keratin, a substance which occurs in a high concentration in both the outer skin (epidermis) and in the skin tissue which occurs at a lower depth in the skin, where the roots 15 of the hairs 13 are present. A sufficient pulse duration and energy density of the laser beam 7 are furthermore necessary for achieving an effective operation of the hair-removing device 1. A too short pulse duration leads merely to a heating of the root 15 and not to a heating of the tissue present in the immediate vicinity of the root 15. The result is that said tissue remains intact, so that a new root and hair can develop. A too long pulse duration leads to an excessive heating of the tissue present at some distance from the root 15 owing to thermal conduction, which may give rise to skin irritation or even skin damage. Good results are obtained with a pulse duration of the laser beam 7 of between approximately 1 ms and 100 ms and an energy density of the laser beam 7 of between approximately  $15 \text{ J/cm}^2$  and  $50 \text{ J/cm}^2$ .

The laser beam 7 can be accurately positioned in the target position 9 by means of the laser beam manipulator 5 in a manner to be described in more detail below, while the target position 9 can be accurately determined by means of an electrical control unit 17 of the hair-removing device 1 in a manner to be described in more detail below. As a result, the laser beam 7 need have only a comparatively small spot diameter for heating the root 15. Good results are obtained at a spot diameter of the laser beam 7 of between approximately 0.3 mm and 1.0 mm. This comparatively small spot diameter means that the laser source 3 need have

only a comparatively low output power of a few watts for achieving the required energy density and pulse duration of the laser beam 7. The laser source 3 used in the hair-removing device 1 accordingly comprises only a comparatively small and simple laser diode which is known per se and which is not shown in detail in Fig. 1, or a series of fiber-coupled laser diodes which are known per se and are also not shown in detail in Fig. 1. The laser source 3 further comprises a collimator lens system which is also not shown in Fig. 1 and by means of which the laser beam 7 is directed so as to be substantially parallel.

As Fig. 1 further shows, the laser beam manipulator 5 comprises a first adjustable tilting mirror 19 and a second adjustable tilting mirror 21 which are both positioned at an angle of approximately  $45^\circ$  with respect to a contact surface 23 with which the hair-removing device 1 is to be laid against the skin 11. The first tilting mirror 19 is tiltable through limited angles about a first tilting axis 21 extending in the plane of the first tilting mirror 19 and parallel to the contact surface 23 by means of an actuator 25 which is depicted diagrammatically only in Fig. 1. The second tilting mirror 21 is tiltable through limited angles about a second tilting axis 31 lying in the plane of the second tilting mirror 21 and crossing the first tilting axis 27 approximately perpendicularly by means of an actuator 29 which is also depicted diagrammatically only in Fig. 1. The laser beam 7 supplied by the laser source 3 during operation is reflected by the first tilting mirror 19 and the second tilting mirror 21 through angles of approximately  $45^\circ$ , so that the laser beam 7 hits the skin 11 under treatment substantially perpendicularly in the target position 9 through an opening 33 provided in the contact surface 23. It is noted that the opening 33 may be covered by means of a cover plate of a transparent material. The target position 9 of the laser beam 7 on the skin 11 is displaceable parallel to an X-direction, which lies in the contact surface 23 and which crosses the first tilting axis 27 perpendicularly, in that the first tilting mirror 19 is tilted about the first tilting axis 27 by the actuator 25. The target position 9 of the laser beam 7 on the skin 11 is displaceable parallel to a Y-direction, which also lies in the contact surface 23 and is perpendicular to the X-direction, in that the second tilting mirror 21 is tilted about the second tilting axis 31 by the actuator 29.

As Fig. 1 further shows, the hair-removing device 1 comprises a separate illumination member 35 by means of which a portion of the skin 11 under treatment present below the opening 33 is illuminated during operation. The illumination member 35 may be a simple lamp. A light beam 37 supplied by the illumination member 35 during operation falls through a transparent plate 39, which also transmits the laser beam 7, onto said portion of the skin 11. The transparent plate 39 is positioned at an angle of approximately  $45^\circ$  with respect to

the contact surface 23 and is provided with a mirroring surface 41 at a side facing the opening 33. A light beam 43 reflected by said portion of the skin 11 is reflected by the mirroring surface 41 through an angle of approximately  $90^\circ$  and focused onto an image sensor 47, a CCD image sensor which is known per se in the embodiment shown, by means of a lens unit 45. The image sensor 47 is thus capable of detecting an image of said portion of the skin 11 present below the opening 33. The use of the illumination member 35 enables the image sensor 47 to detect a clear image of said portion of the skin 11 from the light of the illumination member 35 reflected by the skin 11, so that no reflected light from the laser beam 7 is necessary for detecting said image. This means that the laser source 3 can be fully switched off between the exposures of two consecutive target positions on the skin 11. In addition, the image sensor 47 may be provided with a filter, not shown in Fig. 1, for the reflected light of the laser beam 7, so that the image sensor 47 is protected against damage which may arise as a result of the reflected light of the laser beam 7 when the laser beam 7 is in the target position 9 with a high energy density.

As Fig. 1 shows, the image sensor 47 delivers to the control unit 17 an electrical signal  $u_s$  which corresponds to the image of the portion of the skin 11 present below the opening 33 detected by the image sensor 47, said signal  $u_s$  comprising, for example, a series of 8-bit grey tone values of the image sensor pixels. The detected image is shown diagrammatically in Fig. 3 and indicated with reference numeral 49. As Fig. 4 shows, the control unit 17 comprises a first processor 51, which scans the detected image 49 in a more or less regular manner, said processor 51 generating in succession a number of partial regions 53 of the image 49 as shown in Fig. 3, in particular a more or less regular sequence of partial regions 53 which lie approximately on a number of lines which lie one behind the other as seen in the Y-direction and which extend parallel to the X-direction. The first processor 51 supplies to a second processor 55 of the control unit 17 an electrical signal  $u_{sp}$  which corresponds in succession to the partial regions 53 of the image 49 successively generated by the first processor 51. The second processor 55 determines in each partial region 53 the position and the orientation on the skin 11 of the hair or hairs 13 present in the relevant partial region 53, and supplies an electrical signal  $u_{p0}$  to a third processor 57 of the control unit 17 which corresponds in succession to the positions and orientations of the hairs 13 in the consecutive partial regions 53 of the image 49 as determined by the second processor 55. The third processor 57 determines in each partial region 53 one or several target positions for the laser beam 7 as a function of said position and orientation of the hair or hairs 13 in the relevant partial region 53 in a manner to be described in more detail below. The partial regions 53 have

dimensions which were determined on the basis of a previously determined average distance between the hairs 13 present on the skin 11 and a previously determined length of the hairs 13. In the embodiment shown, the dimensions of the partial regions 53 are such that the partial regions 53 comprise on average only a single hair 13 each. This can be achieved in practice if the user crops the hairs 13 by means of a trimmer prior to the treatment with the hair-removing device 1 to such a length that said previously determined length of the hairs 13 is smaller than said average distance between the hairs 13. Good results are achieved, for example, when the hairs 13 are cropped to a length of between 1 mm and 2 mm for an average distance between the hairs 13 of between 3 mm and 5 mm. It is noted that the first processor 51 generates the consecutive partial regions 53 of the image 49 preferably such that the hair 13 present in a partial region 53 lies approximately in a center of the relevant partial region 53. The sequence of consecutive partial regions 53 then obviously will not have the regularity shown in Fig. 3, but it is more or less regular, with the possibility, for example, of an interspacing being present between consecutive partial regions 53, or with consecutive partial regions 53 lying, for example, not exactly in one line. Since the partial regions 53 on average contain only a single hair 13 each, the position and the orientation of a hair 13 in a partial region 53 and the target positions of the laser beam 7 can be determined within a very short period of time by the second processor 55 of the control unit 17 and by the third processor 57 of the control unit 17, respectively, and a required calculation capacity of the second processor 55 and the third processor 57 can be strongly reduced. Preferably, the hair-removing device 1 further comprises an adjustment member, not shown in the Figures, by means of which the user of the hair-removing device 1 can set the dimensions of the partial regions 53. Said adjustment member for this purpose supplies to the first processor 51 an electrical signal  $u_A$  which corresponds to the dimensions set by the user. The user can thus adapt the dimensions of the partial regions 53 to the properties of the skin to be treated, in particular to the average distance between the hairs on the skin and the average length of the cropped hairs, so that the treatment result and the treatment time can be optimized by the individual user.

As Fig. 4 further shows, the third processor 57 supplies an electrical signal  $u_{TP}$  to a fourth processor 59 of the control unit 17, which signal corresponds consecutively to the target positions of the laser beam 7 determined by the third processor 57 in the consecutive partial regions 53. The fourth processor 59 determines a first output signal  $u_{M1}$  and a second output signal  $u_{M2}$  of the control unit 17, by means of which the control unit 17 controls the first tilting mirror 19 and the second tilting mirror 21 of the laser beam manipulator 5, respectively, as a function of the signal  $u_{TP}$ . The output signals  $u_{M1}$  and  $u_{M2}$  are determined by

the fourth processor 59 such that the tilting mirrors 19 and 21 are adjusted into positions which correspond to the target position of the laser beam 7 in the relevant partial region 53 which corresponds to the signal  $u_{TP}$  each time. The fourth processor 59 also supplies a third output signal  $u_L$  of the control unit 17 by means of which the control unit 17 controls the laser source 3. The fourth processor 59 delivers the output signal  $u_L$  at a predetermined moment after delivering the output signals  $u_{M1}$  and  $u_{M2}$ , said predetermined moment corresponding to a predetermined required adjustment time of the tilting mirrors 19 and 21. The fourth processor 59 supplies the output signal  $u_L$  with the predetermined pulse duration, so that the laser beam 7 is active in the relevant target position for the predetermined pulse duration.

The detected image 49 is regularly scanned by the control unit 17 in the manner described above in accordance with said sequence of consecutive partial regions 53, the laser beam manipulator 5 being adjusted by the control unit 17 into consecutive positions only which correspond to the target positions determined in the consecutive partial regions 53. This means that the laser beam manipulator 5 need be adjusted into a limited number of consecutive positions only, so that a particularly short treatment time is obtained by means of the hair-removing device 1. The laser beam manipulator 5, however, is adjusted in a comparatively irregular manner during this, so that comparatively high requirements are imposed on the adjustment accuracy of the laser beam manipulator 5 and on the adjustment time required for achieving a given adjustment accuracy. The fact that the target positions of the laser beam 7 are automatically determined by the control unit 17, and the fact that the laser source 3 is automatically activated by the control unit 17 after the laser beam manipulator 5 has been automatically adjusted into a correct, accurate position corresponding to a given target position by the control unit 17, render the hair-removing device 1 according to the invention particularly suitable for a safe use by inexperienced persons, so that the hair-removing device 1 is particularly suitable for the consumer market. The determination of the target positions of the laser beam 7 yet to be described in more detail below, the automatic adjustment of the laser beam manipulator 5, and the automatic activation of the laser source 3 take place in a comparatively short period of time, so that comparatively short treatment times are possible with the hair-removing device 1 according to the invention.

The target positions of the laser beam 7 are determined within a partial region 53 of the detected image 49 by the control unit 17 in the following manner. Fig. 5a diagrammatically shows a partial region 53 in which a hair 13 to be epilated is present. The second processor 55 of the control unit 17 determines from the signal  $u_{SP}$  a grey tone distribution for the relevant partial region 53, from which the position and the orientation of

the hair 13 on the skin 11 in the partial region 53 are determined. The second processor 55 also draws a distinction between a hair end 63 and a hair exit position 65 where the hair 13 issues from the skin 11. Said distinction is made by means of predetermined grey tone characteristics and shape characteristics of cropped hair ends and hair exit positions which are stored in the memory of the second processor 55. The third processor 57 of the control unit 17 subsequently determines from the position and orientation of the hair 13 and the exit position 65 thus determined a region 67 on the skin 11 below which the root 15 of the hair 13 will be present with a predetermined degree of probability. In the embodiment shown, it is assumed in the determination of said region 67 that the root 15 is present at a virtual rectilinear subcutaneous extension distance 69 of the hair 13, i.e. extending from the detected exit position 65, while it is further assumed that an angle  $\alpha$  shown in Fig. 2 between the hair 13 and the surface of the skin 11 and a length L, also shown in Fig. 2, of a portion of the hair 13 present below the surface of the skin 11 lie between certain minimum and maximum values which were previously statistically determined. The region 67 thus determined is elongate and extends along a straight line segment 71 which lies on a virtual line which coincides substantially with a perpendicular projection of the hair 13 on the skin 11. The third processor 57 subsequently determines on the line segment 71 thus determined a number, for example three, of fixed target positions 9, 9', and 9'' for the laser beam 7, mutually overlapping by a small portion each time, and the third processor 57 supplies to the fourth processor 59 a number of consecutive signals  $u_{TP}$  which correspond to said target positions 9, 9', and 9''. As a result of this, the fourth processor 59 of the control unit 17 adjusts the laser beam manipulator 5 into a number of consecutive fixed positions which correspond to the target positions 9, 9', and 9'' of the laser beam 7 thus determined, the fourth processor 59 activating the laser source 3 for the predetermined pulse duration in each of the consecutive fixed positions of the laser beam manipulator 5.

Fig. 5b shows a partial region 53 of the detected image 49 in an alternative embodiment of the hair-removing device 1 according to the invention. In this alternative embodiment, the third processor 57 supplies to the fourth processor 59 a signal  $u_{TP}$  which corresponds to a displacement of the laser beam 7 with a predetermined velocity  $v$  over said straight line segment 71, so that the fourth processor 59 adjusts the laser beam manipulator 5 into a sequence of consecutive positions which correspond to said displacement of the laser beam 7. The fourth processor 59 of the control unit 17 in this alternative embodiment activates the laser source 3 at the start of said displacement and the fourth processor 59 switches off the laser source 3 at the end of said displacement. To obtain a result in this alternative

embodiment comparable to the result achieved by the embodiment shown in Fig. 5a, said predetermined velocity  $v$  of the laser beam 7 should be approximately equal to a quotient of the spot diameter of the laser beam 7 and the pulse duration used in Fig. 5a.

In the embodiment shown in Fig. 4, the control unit 17 further comprises a fifth processor 73 which determines a reflection spectrum of the portion of the skin 11 present below the opening 33 from the image 49 detected by the image sensor 47, i.e. from the signal  $u_S$ , and which compares this reflection spectrum with a predetermined reference spectrum which is stored in a memory of the fifth processor 73 and which contains information characteristic of at least one frequently occurring skin deviation. Fig. 6 shows an example of such a reflection spectrum, wherein the horizontal axis represent a measured grey tone  $G$  and the vertical axis a number of image sensor pixels  $N$ . The reflection spectrum shown comprises a first, comparatively great peak A with grey tones corresponding to a white skin, a second, comparatively small peak B with grey tones corresponding to dark hairs, and a third peak C with grey tones corresponding to said skin deviation. The fifth processor 73 determines from said comparison the positions on the skin 11 where said skin deviation occurs and supplies to a sixth processor 75 of the control unit 17 an electrical signal  $u_{BP}$  which corresponds to the positions on the skin 11 of said skin deviation thus determined. The sixth processor 75 compares the signal  $u_{TP}$ , which corresponds to a target position of the laser beam 7 determined by the third processor 57, with the positions on the skin 11 of said skin deviation thus determined, and supplies a signal  $u_{STOP}$  to the fourth processor 59 whenever the target position of the laser beam 7 coincides with one of the positions of said skin deviation on the skin 11. When the fourth processor 59 receives the signal  $u_{STOP}$ , the laser source 3 is not activated by the fourth processor 59. The use of the fifth processor 73 and the sixth processor 75 prevents the laser beam 7 from being active in positions on the skin 11 where said skin deviation is present. Examples of this are moles or other pigment spots. Such skin deviations have a comparatively high absorption power for the light of the laser beam 7 used, so that injuries may arise in the case of contact of these skin deviations with the light of the laser beam 7. The use of the fifth processor 73 and the sixth processor 75 provides an automatic protection against such injuries.

In the embodiment shown in Fig. 4, the fourth processor 59 determines the output signals  $u_{M1}$  and  $u_{M2}$  in accordance with a predetermined mathematical relation between the output signals  $u_{M1}$ ,  $u_{M2}$  and the desired target position 9 of the laser beam 7 as determined by the third processor 57. Said mathematical relation is, for example, a linear function or a function of a higher degree comprising a number of coefficients. As a result of temperature



fluctuations or other factors, deviations of the target position 9 resulting from a predetermined value of the output signals  $u_{M1}$ ,  $u_{M2}$  may arise. Such deviations can lead to a reduced efficiency of the hair-removing device 1 and to skin irritations or damages. To reduce or avoid such deviations and provide a very accurate positioning of the laser beam 7 on the skin 11 by the mirrors 19, 21, the control unit 17 further comprises a calibration member 81 for calibrating said predetermined mathematical relation on the basis of a measured relation between the output signals  $u_{M1}$ ,  $u_{M2}$  and an actual position of the laser beam 7 on the skin 11. Said calibration, for example, constitutes a re-calculation of said coefficients of the predetermined mathematical relation on the basis of the measured relation between the output signals  $u_{M1}$ ,  $u_{M2}$  and the actual position of the laser beam 7 on the skin 11, and is carried out by the control unit 17, for example, each time the hair-removing device 1 is started or each time after a predetermined time interval. To carry out said calibration, the mirrors 19, 21 are consecutively positioned in a predetermined number of calibration positions. For this purpose, the fourth processor 59 consecutively supplies a predetermined number of output signals  $u_{M1}$ ,  $u_{M2}$  having predetermined values. In each calibration position of the mirrors 19, 21, the actual position of the laser beam 7 on the skin 11 is determined by means of a seventh processor 83 of the control unit 17, which determines said actual position from the image detected by the image sensor 47. For this purpose, as shown in Fig. 4, the seventh processor 83 receives the signal  $u_S$  supplied by the image sensor 47, and supplies a signal  $u_{AP}$  corresponding to the actual position of the laser beam 7 on the skin 11 to the calibration member 81. After the determination of the actual position of the laser beam 7 in each calibration position of the mirrors 19, 21, the calibration member 81 supplies a signal  $u_{CAL}$  corresponding to the re-calculated coefficients of the predetermined mathematical relation to the fourth processor 59. During said calibration process, the fourth processor 59 activates the laser source 3 at a comparatively low energy density via a suitable value of the signal  $u_L$ . Said energy density is as low as possible, but such that the spot of the laser beam 7 on the skin 11 is still sufficiently bright to be detected by the image sensor 47. In this manner, skin irritation or damage are prevented during the calibration process, and the energy consumption of the laser source 3 is limited. It is noted, that the invention also comprises embodiments, in which the actual position of the laser beam 7 on the skin 11 is determined in a similar manner from the image detected by the image sensor 47, but in which the laser beam manipulator 5 is corrected in a different manner. The control unit 17 may, for example, alternatively be provided with a feed back control circuit comprising a comparator, which compares the actual position of the laser beam with the desired target position and supplies an error signal, and a PID regulator, which

determines the output signals  $u_{M1}$  and  $u_{M2}$  on the basis of said error signal in such a manner that the measured actual position equals the desired target position. The invention also comprises embodiments, in which the actual position of the laser beam on the skin is not determined by means of the image sensor, but by means of a separate sensor means such as, for example, sensors which directly measure the angular positions of the mirrors 19, 21.

As Fig. 1 shows, the hair-removing device 1 according to the invention further comprises a handle 81 by means of which the user can place the hair-removing device 1 on the skin 11 to be treated and can displace it over the skin 11. As was described above, the portion of the skin 11 present below the opening 33 only is treated. After the treatment of said portion of the skin 11, the user should displace the hair-removing device 1 into a next position on the skin 11. The hair-removing device 1 may be provided, for example, with an acoustic source which is triggered by the control unit 17 and which produces an acoustic signal the moment the treatment of the portion of the skin 11 present below the opening 33 has been completed. The hair-removing device 1 may alternatively be provided, for example, with electrical drive means controlled by the control unit 17 for the automatic displacement of the hair-removing device 1 over the skin 11 to be treated, instead of with such an acoustic source.

Fig. 7 shows a control unit 17' of a further embodiment of a hair-removing device 1' according to the invention. Apart from the control device 17', the hair-removing device 1' has a composition comparable to that of the hair-removing device 1 according to the invention shown in Fig. 1. Components of the hair-removing device 1' corresponding to components of the hair-removing device 1 described above have been given the same reference numerals in Fig. 7, and the description below will deal exclusively with the differences between the control units 17 and 17' and the resulting differences in operation between the hair-removing devices 1 and 1'.

As Fig. 7 shows, the control unit 17' likewise comprises a first processor 51, a second processor 55, a third processor 57, a fourth processor 59, a fifth processor 73, and a sixth processor 75. The control unit 17' comprises furthermore a seventh processor 77 which determines the first output signal  $u_{M1}$  and the second output signal  $u_{M2}$  by means of which the control unit 17' controls the first tilting mirror 19 and the second tilting mirror 21 of the laser beam manipulator 5, respectively. The control unit 17' likewise comprises a calibration member 81 and an eighth processor 83, which correspond with the calibration member 81 and the seventh processor 83 of the control unit 17 and which cooperate with the image sensor 47 and the seventh processor 77 in a manner similar to the manner in which the calibration member 81 and the seventh processor 83 of the control unit 17 correspond with the image

sensor 47 and the fourth processor 59. The seventh processor 77 determines the output signals  $u_{M1}$  and  $u_{M2}$  such that the tilting mirrors 19 and 21 are adjustable into a sequence of consecutive positions which correspond to a regular sequence of virtual positions of the laser beam 7 on the portion of the skin 11 below the opening 33, in particular with a displacement of the virtual position of the laser beam 7 with a predetermined velocity  $v'$  in accordance with a number of lines extending parallel to the X-direction and following one another as seen in the Y-direction. As Fig. 7 shows, the seventh processor 77 here supplies to the first processor 51 an electrical signal  $u_{IP}$  which corresponds to the instantaneous virtual position IP of the laser beam 7. The first processor 51 generates from the signals  $u_S$  and  $u_{IP}$  a partial region 53' of the image 49 which is diagrammatically shown in Fig. 8 and which has dimensions determined by a previously determined average distance between the hairs 13 present on the skin 11 and a previously determined length of the hairs 13. The dimensions of the partial region 53' can be set by the user by means of an adjustment member which is not shown and which supplies to the first processor 51 an electrical signal  $u_A$  which corresponds to the dimensions of the partial region 53' as set by the user. The first processor 51 generates the partial region 53' such that a reference position R in the partial region 53' shown in Fig. 8, in particular a central position of the partial region 53', corresponds continually to the instantaneous virtual position IP of the laser beam 7. The partial region 53' thus follows the rectilinear displacement of the instantaneous virtual position IP of the laser beam 7 over the image 49. Fig. 8 also shows a number of lines 79 along which the instantaneous virtual position IP of the laser beam 7 is displaced over the image 49. The first processor 51 supplies to the second processor 55 an electrical signal  $u_{SP}$  which corresponds to the partial region 53', and the second processor 55 determines from the signal  $u_{SP}$  the position and the orientation in the partial region 53' of the hair 13 present in the partial region 53'. The second processor 55 supplies to the third processor 57 an electrical signal  $u_{PO}$  which corresponds to the position and the orientation of the hair 13 in the partial region 53' as determined by the second processor 55, and the third processor 57 determines from the signal  $u_{PO}$  the target positions 9, 9', and 9'' of the laser beam 7 in the partial region 53'. The third processor 57 supplies to the fourth processor 59 an electrical signal  $u_{TP}$  which corresponds to the target positions 9, 9', and 9'' of the laser beam 7 as determined by the third processor 57. The fourth processor 59 compares the instantaneous virtual position IP of the laser beam 7 with the target positions 9, 9', and 9'' of the laser beam 7 and activates the laser source 3 by means of the output signal  $u_L$  during the previously determined pulse duration whenever the instantaneous virtual position IP of the laser beam 7 corresponds to one of the target positions 9, 9', or 9'' of the laser beam 7 in

the partial region 53'. The fifth processor 73 and the sixth processor 75 in the control unit 17' have functions comparable to those of the fifth processor 73 and the sixth processor 75 in the control unit 17.

An advantage of the hair-removing device 1' with the control unit 17' is that the laser beam manipulator 5 is continually adjusted by the control unit 17' in a regular manner, so that the laser beam manipulator 5 need not have an exceptionally high adjustment accuracy and an exceptionally short adjustment time. The portion of the skin 11 present below the opening 33 is scanned by the laser beam manipulator 5 in a regular manner, and the partial region 53' of the image 49 generated by the control unit 17' follows the virtual position IP of the laser beam 7 on said portion of the skin 11, the target positions 9, 9', and 9'' of the laser beam 7 changing continually with respect to the reference point R of the partial region 53'. Good results are obtained in this further embodiment of the hair-removing device 1' when an interspacing is present between the consecutive lines 79 in the image 49 which is equal to or is preferably smaller than the spot diameter of the laser beam 7. However, scanning of all lines 79 present in the image 49 by the laser beam manipulator 5 takes longer than the direct displacement of the laser beam manipulator 5 into the consecutive target positions in the image 49 as in the hair-removing device 1, so that the hair-removing device 1' will have a longer treatment time than the hair-removing device 1 in most cases.

The hair-removing devices 1 and 1' described above are epilation devices by means of which hairs 13 are removed from the skin 11 for a comparatively long period or even permanently. A yet further embodiment of a hair-removing device 1'' according to the invention operates as a shaver. The hair-removing device 1'' has a construction which is largely identical to the construction of the hair-removing device 1 shown in Fig. 1. The hair-removing device 1'' differs from the hair-removing device 1 in that the hair-removing device 1'' determines the target position 9 of the laser beam 7 on the skin 11 in a different manner. Fig. 9 diagrammatically shows a partial region 53'' of the image 49 of the skin 11 under treatment which is detected by means of the image sensor 47 of the hair-removing device 1''. The third processor 57 of the control unit 17 of the hair-removing device 1'' determines the target position 9 of the laser beam 7 such that this target position 9 lies on the hair 13 to be removed adjacent the exit position 65 of the hair 13 determined by the second processor 55. The hair 13 is thus burnt through by the laser beam 7 adjacent the exit position 65. The control unit 17 of the hair-removing device 1'' can be so programmed that the target position 7 lies flush with or even below the surface of the skin 11, so that a very smooth shaving result is achieved with the hair-removing device 1'', which is maintained for a comparatively long

period. The hair-removing device 1" may be further provided with an adjustment member by means of which the user can adjust the location of the target position 9 relative to the surface of the skin 11, thus adjusting a desired smoothness. It was found that the burning-through of hairs 13 by means of the laser beam 7 is possible at an energy density of the laser beam 7 which is considerably smaller than the energy density necessary for the epilation of the hairs 13 as described above. The hair-removing device 1" may thus be provided with a comparatively small and inexpensive laser diode with a power of, for example, between 100 mW and 500 mW.

It is noted that the invention also covers a hair-removing device in which the epilation function and the shaving function as described above are combined, in which case the user can select the desired mode of operation, for example by means of an adjustment member. Preferably, the energy density of the laser source is also controllable by means of the control unit of such a hair-removing device, so that the energy density of the laser source can be adapted to the desired mode of operation of the hair-removing device. If the hair-removing device has an epilation function or has been set as an epilation device by the user, the hair-removing device may also be provided, for example, with an automatic shaving function. If the hair-removing device has exclusively an epilation function, in which case exclusively the roots 15 of the hairs 13 are destroyed, the hairs 13 will not disappear from the skin 11 until after some time, so that the desired result is not achieved immediately. If the epilation function of the hair-removing device is automatically combined with a shaving function, it is not only the roots 15 of the hairs 13 which are destroyed, but the hairs 13 are also burnt through adjacent the surface of the skin 11, so that the hairs 13 are immediately removed from the skin 11 and the desired result is achieved instantaneously.

It is further noted that a hair-removing device according to the invention may be provided with a different type of laser beam manipulator instead of the laser beam manipulator 5 having the two tilting mirrors 19 and 21 as described above. Thus, for example, the two tilting mirrors 19 and 21 may be replaced by a single tilting mirror which is tiltable about two mutually perpendicular tilting axes. Instead of a laser beam manipulator with one or more than one tilting mirror, for example, a laser beam manipulator may alternatively be used which is provided with an object holder which is displaceable in two mutually perpendicular directions, in which case the laser source and the image sensor are fastened to said object holder in fixed positions.

It is further noted that the invention also covers embodiments of the hair-removing device in which a type of image sensor is used different from the image sensor 47

with CCD as described above. An example of such an image sensor is a CMOS image sensor. Such a CMOS image sensor may be provided with a RAM memory, so that part of the control unit or even the entire control unit of the hair-removing device can be integrated with the CMOS image sensor. The construction and manufacture of the hair-removing device are  
5 considerably simplified in this manner.

In the embodiments of the hair-removing device according to the invention described above, the control unit determines the target position of the laser beam each time in a partial region of the image of the skin detected by means of the image sensor. It is noted that the invention also relates to embodiments in which the control unit determines the target  
10 positions of the laser beam once and for all in the entire image of the skin detected by the image sensor. Such embodiments, however, require a control unit with a comparatively great calculation capacity and memory capacity.

It is finally noted that the invention also relates to embodiments of the hair-removing device in which the positions of the hairs on the skin under treatment are not  
15 detected by means of reflected light of a separate illumination member, such as the illumination member 35 described above, but in which the positions of the hairs are detected by means of reflected light from the laser beam. The skin to be treated is scanned by means of the laser beam in such embodiments, during which the laser beam has a comparatively low energy density, which energy density of the laser beam is temporarily raised in the target  
20 position. The reflected light of the laser beam may be detected in such embodiments, for example, by means of a simple photodetector which detects only the intensity of the reflected light of the laser beam. The expression "image sensor for detecting an image of at least a portion of the skin" in the claims therefore also relates to such a comparatively simple photodetector. Such a method of detection may be used in a comparatively simple manner in  
25 the hair-removing device 1' described with reference to Fig. 7, but it may also be used in, for example, a hair-removing device provided with a laser beam manipulator with a displaceable object holder as described above.

## CLAIMS:

1. A hair-removing device provided with a laser source, an adjustable laser beam manipulator for positioning a laser beam supplied by the laser source during operation in a target position on a skin to be treated, and an image sensor for detecting an image of at least a portion of the skin, characterized in that the laser source is controllable by means of an  
5 electrical control unit, which control unit during operation determines the target position of the laser beam as a function of a position and/or orientation on the skin of a hair to be removed as determined from the image by the control unit, and which control unit activates the laser source the moment the laser beam manipulator is in a position which corresponds to the target position of the laser beam.

10 2. A hair-removing device as claimed in claim 1, characterized in that the control unit determines the target position of the laser beam in a partial region of the image having dimensions which are determined by a previously determined average distance between hairs present on the skin and a previously determined length of the hairs.

15 3. A hair-removing device as claimed in claim 2, characterized in that the dimensions of the partial region of the image are adjustable.

20 4. A hair-removing device as claimed in claim 2, characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a regular sequence of virtual positions of the laser beam on said portion of the skin, a reference position in the partial region of the image corresponding to the instantaneous virtual position of the laser beam, and the control unit activating the laser source when the reference position corresponds to the target position of the laser beam.

25 5. A hair-removing device as claimed in claim 2, characterized in that the control unit determines the target position of the laser beam in a regular sequence of consecutive partial regions of the image, the laser beam manipulator being adjustable by means of the

control unit in each of said partial regions into a position which corresponds to the target position of the laser beam in the relevant partial region.

6. A hair-removing device as claimed in claim 1, characterized in that the control unit determines from the position and orientation on the skin of the hair to be removed, as determined from the image, a region on the skin below which a root of the hair will be present with a predetermined degree of probability, the control unit determining at least one target position on the skin in said region.
7. A hair-removing device as claimed in claims 5 and 6, characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a displacement of the laser beam over a rectilinear path on the skin with a predetermined velocity, said rectilinear path lying on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source at the start of said displacement.
8. A hair-removing device as claimed in claims 5 and 6, characterized in that the laser beam manipulator is adjustable by means of the control unit into a number of consecutive fixed positions corresponding to a number of fixed target positions of the laser beam on a rectilinear path on the skin, which rectilinear path lies on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source in each of said fixed positions of the laser beam manipulator during a predetermined time.
9. A hair-removing device as claimed in claim 1, characterized in that the control unit determines an exit position on the hair, where the hair issues from the skin, from the position and orientation on the skin of the hair to be removed as determined from the image, the control unit equalizing the target position of the laser beam with a position on the hair adjacent said exit position.
10. A hair-removing device as claimed in claim 1, characterized in that the hair-removing device comprises a separate illumination member for illuminating at least the portion of the skin which is to be detected by the image sensor.



11. A hair-removing device as claimed in claim 1, characterized in that the control unit determines from the image a reflection spectrum of the skin portion detected by the image sensor, the control unit comparing the reflection spectrum with a predetermined reference spectrum of at least one frequently occurring skin deviation, while the control unit determines  
5 from said comparison positions on the skin in which said skin deviation is present and does not activate the laser source in said positions on the skin.

12. A hair-removing device as claimed in claim 1, characterized in that the control unit comprises means for determining an actual position of the laser beam on the skin from the  
10 image detected by the image sensor.

13. A hair-removing device as claimed in claim 12, characterized in that the laser beam manipulator is adjustable by means of the control unit via an output signal of the control unit in accordance with a predetermined mathematical relation between said output signal and  
15 the target position, the control unit comprising a calibration member for calibrating said predetermined mathematical relation on the basis of a measured relation between said output signal and the actual position of the laser beam on the skin.

14. A hair-removing device as claimed in claim 12, characterized in that, for  
20 determining the actual position of the laser beam on the skin, the control unit activates the laser source at a comparatively low energy density.

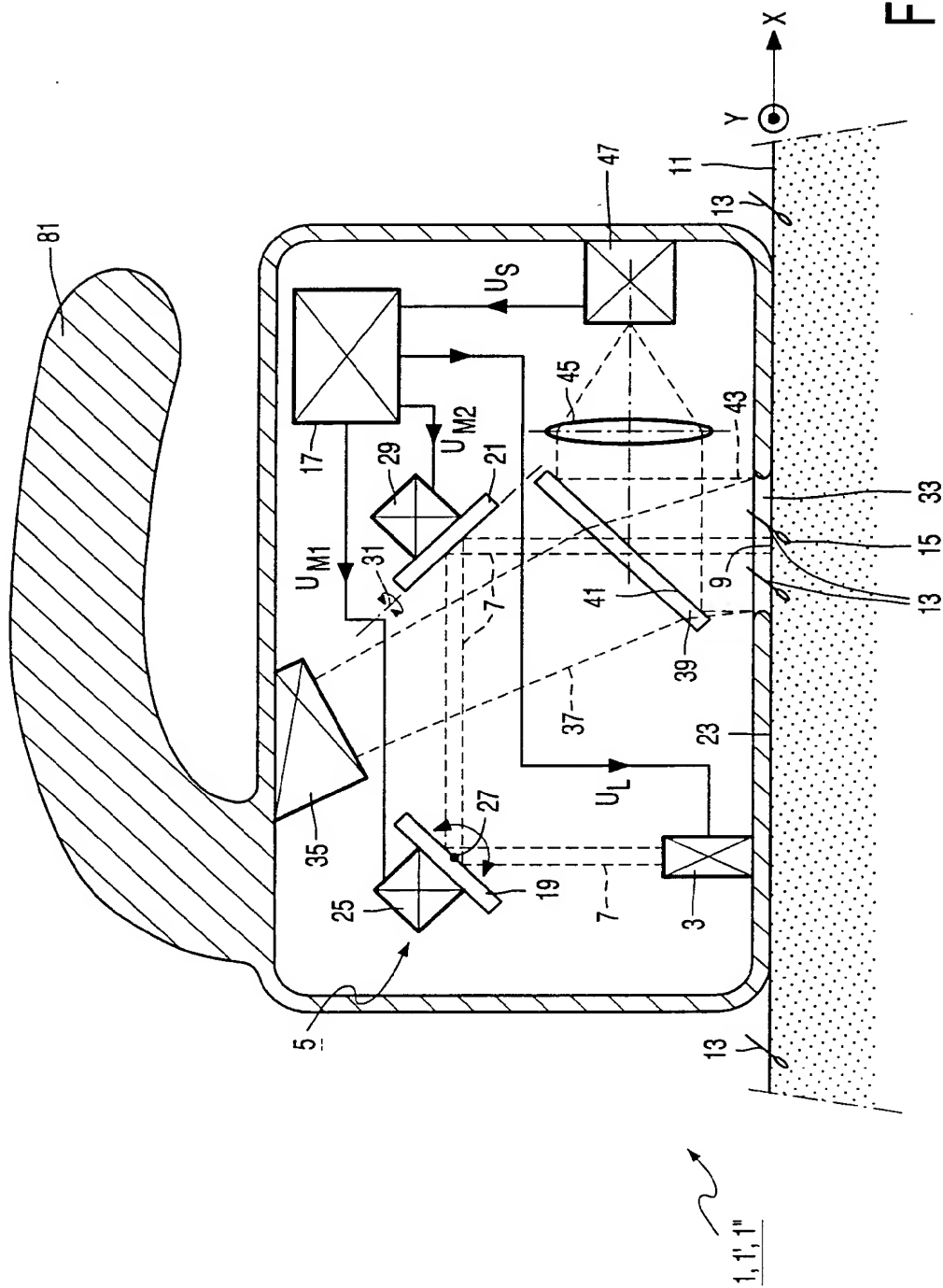


FIG. 1

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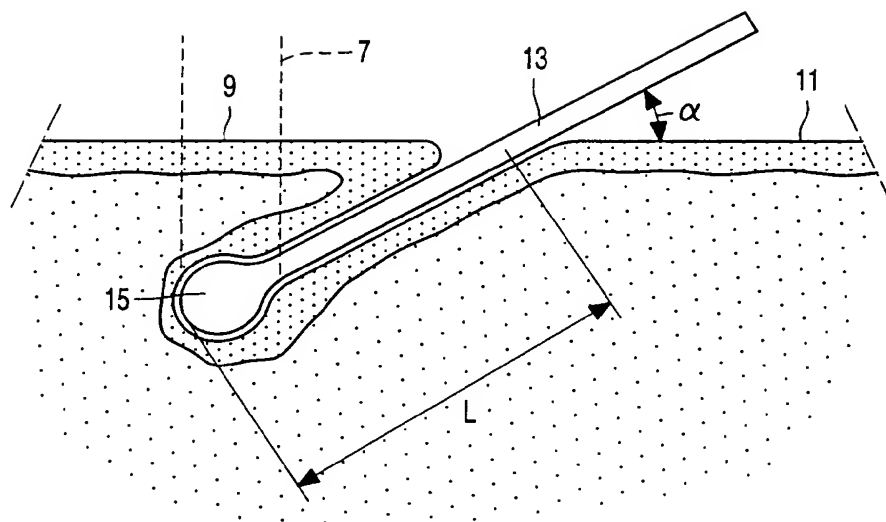


FIG. 2

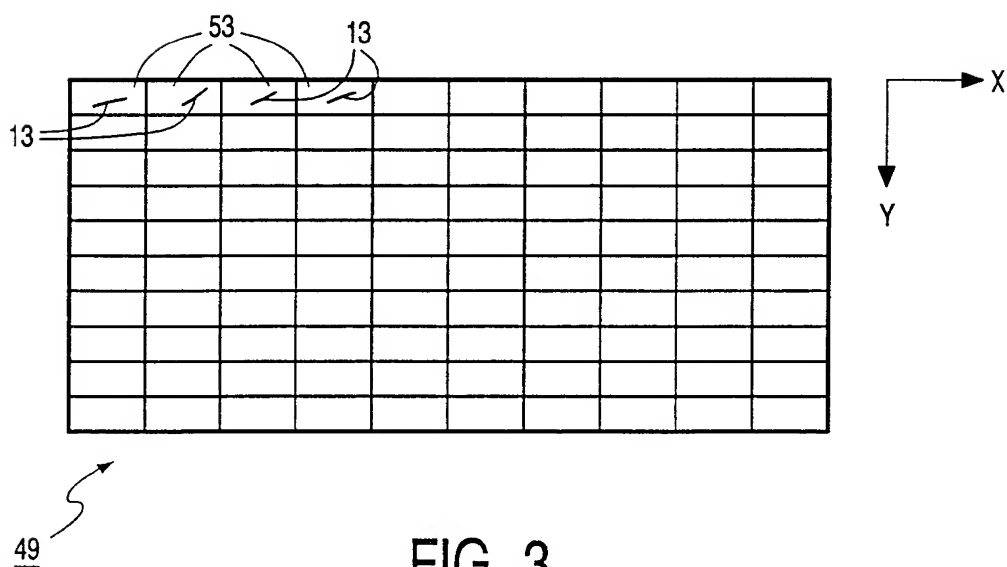


FIG. 3

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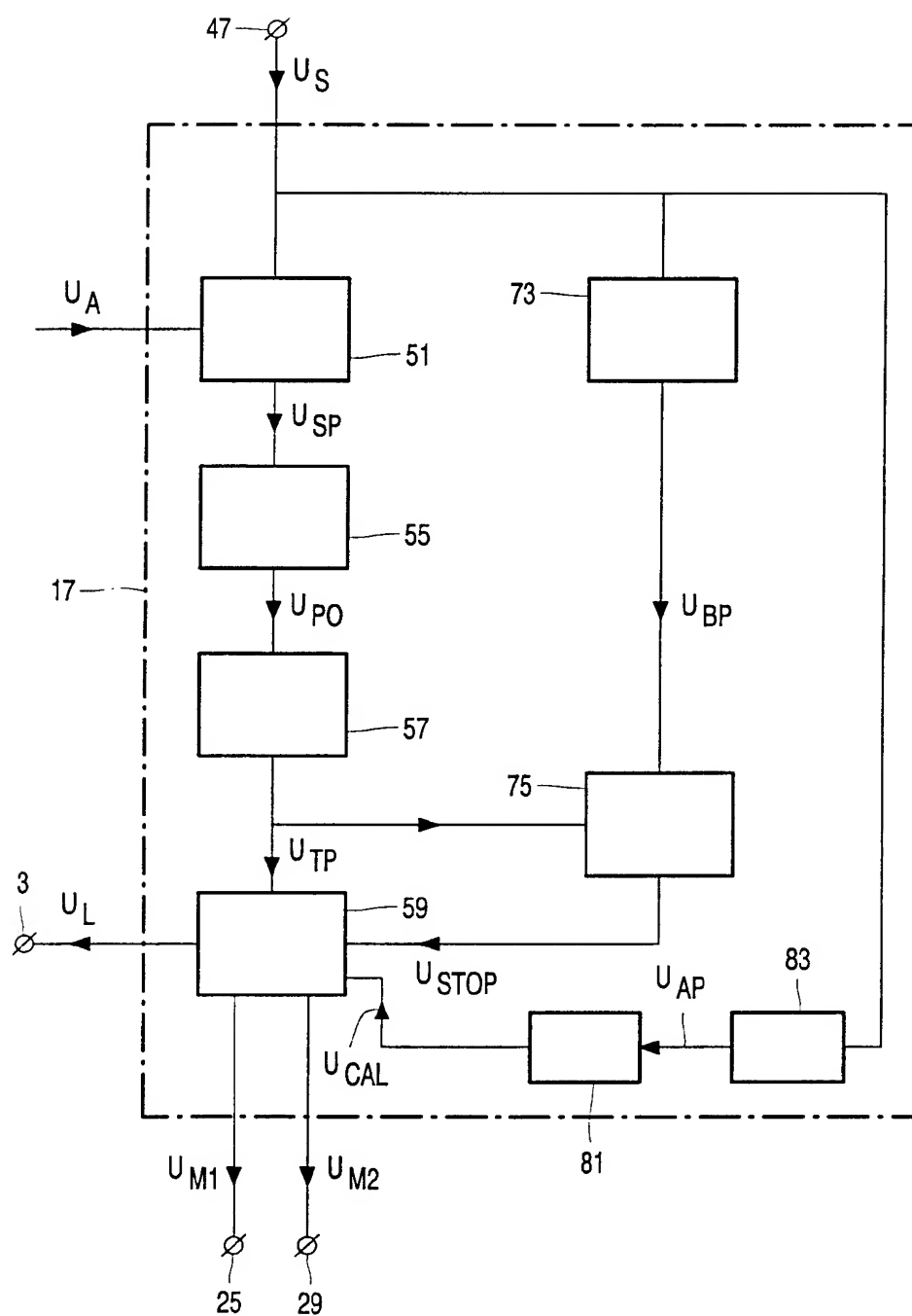


FIG. 4

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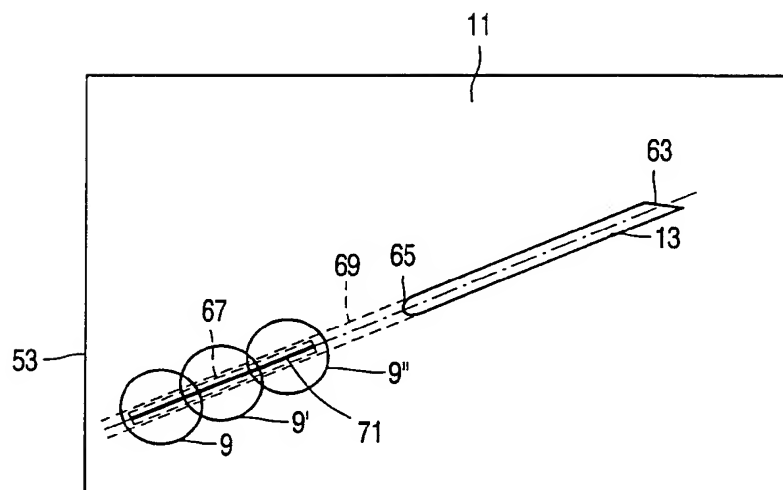


FIG. 5A

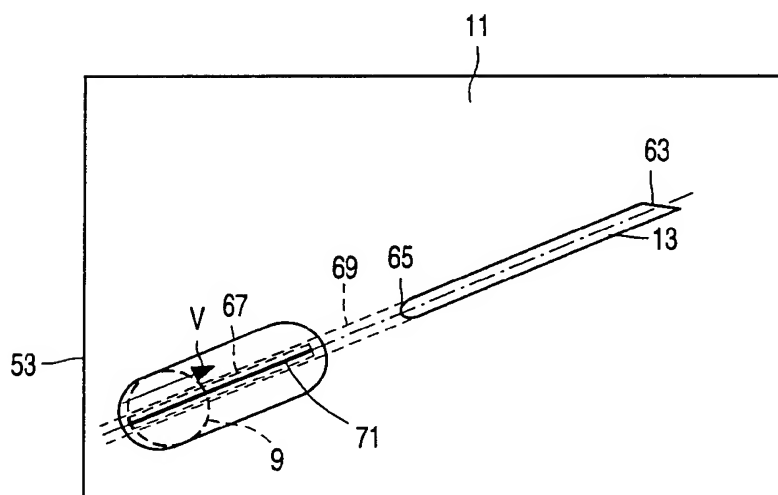


FIG. 5B

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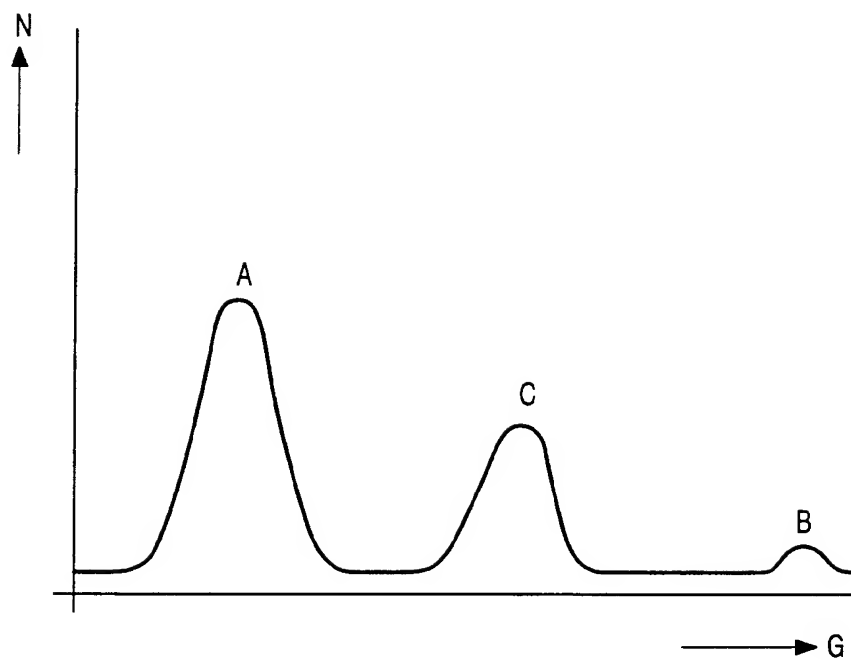


FIG. 6

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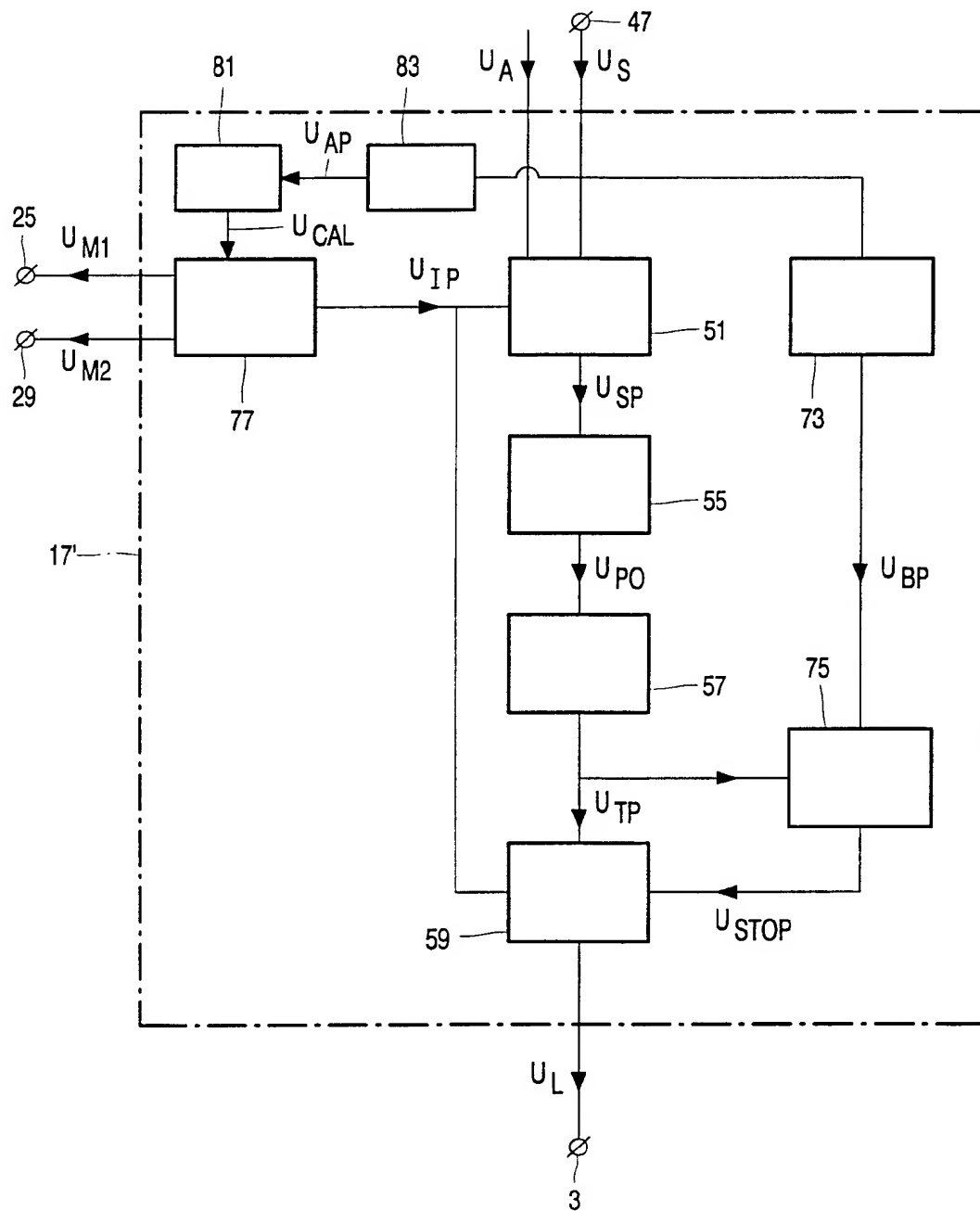
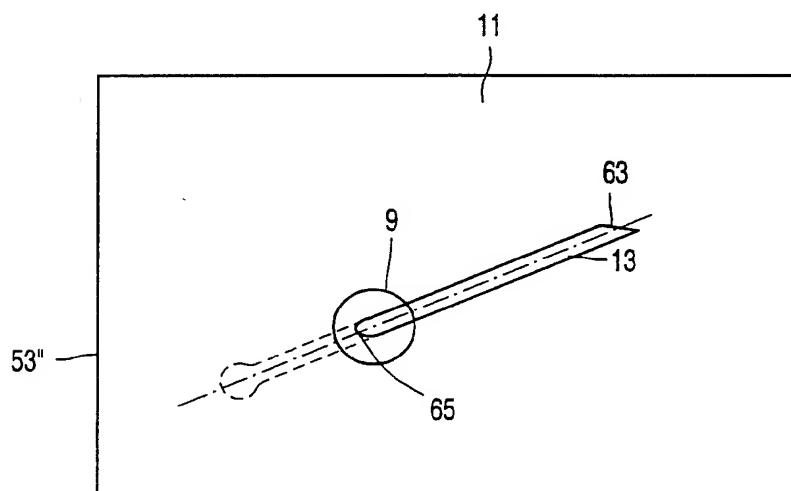
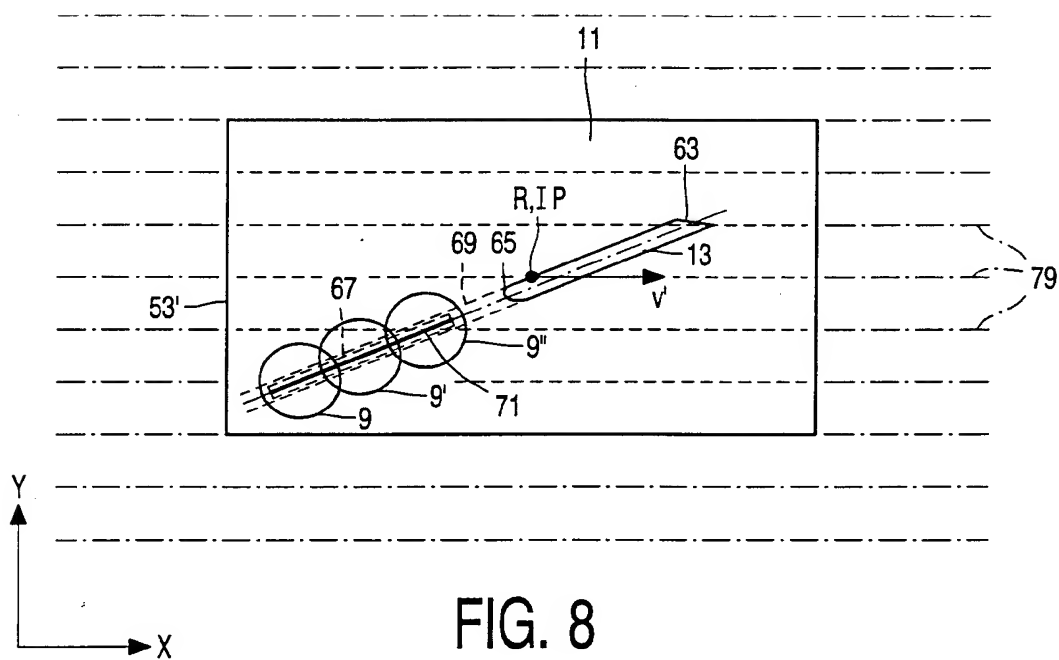


FIG. 7

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 00/02871

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61B18/20

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 11324 A (BALLE PETERSEN OLAV ;ASA BJARNE (DK); ASAH MEDICO A S (DK); DOLLE) 11 March 1999 (1999-03-11) page 3, line 12 - line 17 page 10, line 2 - line 9 page 12, line 7 - line 15 page 14, line 8 - line 10 page 19, line 33 -page 20, line 13	1, 10, 11
Y	---	12
Y	EP 0 880 941 A (NIDEK KK) 2 December 1998 (1998-12-02) column 7, line 7 -column 8, line 45 column 11, line 56 -column 12, line 18 ---	12
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☒ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

11 August 2000

Date of mailing of the international search report

21/08/2000

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# INTERNATIONAL SEARCH REPORT

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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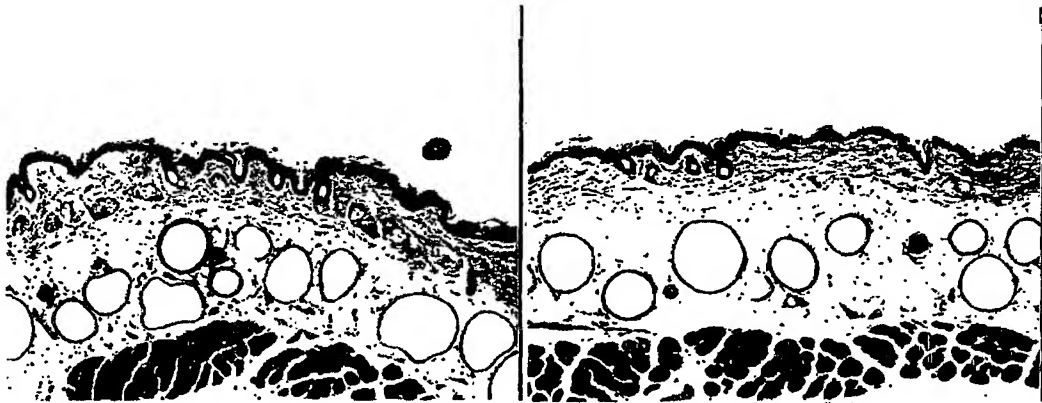
information on patent family members

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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b>  <b>A61N 5/06</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/64537</b>  <b>(43) International Publication Date:</b> 2 November 2000 (02.11.00)
<b>(21) International Application Number:</b> PCT/US00/11248 <b>(22) International Filing Date:</b> 27 April 2000 (27.04.00)  <b>(30) Priority Data:</b> 60/131,313                      27 April 1999 (27.04.99)                      US  <b>(71) Applicant:</b> THE GENERAL HOSPITAL CORPORATION doing business as MASSACHUSETTS GENERAL HOSPITAL [US/US]; 55 Fruit Street, Boston, MA 02114 (US).  <b>(72) Inventors:</b> KOLLIAS, Nikiforos; 406 Sunset Road, Skillman, NJ 08558 (US). GILLIES, Robert; 388 Ocean Avenue, Apt. 1212, Revere, MA 02151 (US). TIAN, Wei, Dong; 10 Alhambra Road, West Roxbury, MA 02132 (US).  <b>(74) Agents:</b> ROTHENBERGER, Scott, D. et al.; Nutter, McClen- nen & Fish, LLP, One International Place, Boston, MA 02110-2699 (US).		<b>(81) Designated States:</b> CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> PHOTOTHERAPY METHOD FOR TREATMENT OF ACNE  <div style="text-align: center;">  </div>		
<b>(57) Abstract</b>  <p>The present invention is directed to methods for treating acne. The methods include exposing the subject afflicted with acne to ultraviolet light having a wavelength between about 320 to about 350 nm, such that the acne is treated e.g., inhibited, diminished, eradicated or prevented. In a preferred embodiment, the wavelength is 335 nm and is emitted by either a nitrogen laser or a third harmonic of a NdYAG laser. Treatments can be administered over a several week period, where the subject is exposed to sequential doses of ultraviolet light to obtain beneficial effects e.g., a reduction or elimination of the acne, e.g., an eradication or diminishment of the bacteria responsible for acne, e.g., <i>Propionibacterium acnes</i>.</p>		

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## PHOTOTHERAPY METHOD FOR TREATMENT OF ACNE

### BACKGROUND OF THE INVENTION

Acne is one of the most frequently presented dermatologic conditions. To date  
5 there is no single widely accepted treatment modality although a number of approaches  
exist. These approaches include topical or systemic antibiotics, benzoyl peroxide gels,  
oral 13-cis-retinoic acid, or hormones. Acne lesions (comedones) are the result of a  
complex interaction between hormones (androgens) and bacteria (*Propionibacterium*  
*acnes*) in the pilosebaceous unit. Acne results when the opening of the sebaceous  
10 glands is occluded, resulting in accumulation of sebum and fatty acids produced by the  
bacteria through lipase breakdown of lipids. The increase in sebum results in  
enlargement of the glands which in turn leads to inflammation and eventually to rupture  
of the glandular envelop. Release of the gland contents into the dermis produces  
changes in the structural matrix and may result in scarring. While acne is not a life  
15 threatening condition, it frequently produces discomfort, and can be disfiguring to a  
subject due to scarring.

Exposure of the skin to ultraviolet radiation has been reported to result in  
enlargement of the sebaceous glands. This has been found in photoaging studies in  
hairless mice. It is also known that sun exposure results in amelioration of acne. The  
20 response to sunlight may be either due to photodynamic activity (PDT) of  
coproporphyrin produced by the bacteria, *Propionibacterium acnes*, or due to an effect  
of the sunlight to the cell differentiation and proliferation. The PDT effect would lead  
to destruction of the bacteria which in turn would lead to improvement of acne. In this  
case, short wavelength visible radiation (405-410 nm) should be equally effective in  
25 improving acne. However, there is substantial evidence that both light and antibiotics  
reduce the fluorescence produced by coproporphyrin, the loss of which is not always  
related to amelioration of the acne condition.

### SUMMARY OF THE INVENTION

30 The present invention is directed to methods for treating acne. The methods  
include exposing the subject afflicted with acne to ultraviolet light having a wavelength  
between about 320 to about 350 nm, such that the acne is treated, e.g., inhibited,  
diminished, eradicated or prevented. In a preferred embodiment, the wavelength is 335  
nm and is emitted by a nitrogen laser, a third harmonic of a NdYAG laser, a tunable

OPO laser (Optical Parametric Oscillator), or a properly filtered mercury lamp or continuous wave lamp. Treatments can be administered over a several week period, where the subject is exposed to sequential doses of ultraviolet light to obtain beneficial effects, e.g., a reduction or elimination of the acne, e.g., eradication or diminishment of the bacteria responsible for acne, e.g., *Propionibacterium acnes*.

The present invention is also directed to methods for preventing acne. The methods include exposing the subject afflicted with acne to ultraviolet light having a wavelength between about 320 nm to about 350 nm, such that acne is prevented. In one embodiment, ultraviolet wavelengths useful in the invention are between about 325 nm to about 345 nm, preferably between about 330 to about 340 nm, more preferably between about 332 and about 337 nm, and most preferred at 335 nm.

The present invention is also directed to methods for reducing the amount or size of sebaceous glands in a subject. The methods include exposing the subject to ultraviolet light having a wavelength between about 320 and 350 nm, such that the amount or size of sebaceous glands in the subject are reduced.

The present invention is further directed to methods for treating disease states or conditions which cause or are associated with the generation of excess of sebum in sebaceous glands. The invention is also directed to methods for treating disease states or conditions which cause or are associated with the occlusion of sebaceous glands with accumulation of sebum and fatty acids produced by bacteria through lipase breakdown of lipids. These methods include exposing the subject to ultraviolet light having a wavelength between about 320 and 350 nm, such that the buildup of sebum and/or lipids in the sebaceous glands of the pilosebaceous units of the subject are reduced.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a histological section of hairless mouse skin exposed to 335 nm narrow band radiation. Note the absence of sebaceous glands in the exposed site (right), as opposed to the unexposed site (left).

Fig. 2. includes images of the superficial dermis of hairless mouse skin obtained *in vivo* with an infrared (1.06  $\mu\text{m}$ ) Laser Scanning Confocal Microscope.

Four control images corresponding to adjacent skin sites of unexposed hairless mouse skin at a depth of approximately 100  $\mu\text{m}$ , with the sebaceous glands appearing at this depth as large ellipsoidal bodies (left panel), and four adjacent skin sites that received nine (9) exposures of 335 nm narrow band radiation at 7 J/cm<sup>2</sup> per exposure which corresponds to 0.25 of a minimum erythema dose (MED) at this wavelength (right panel). (Unstained sections, 30 x magnification, 0.9 NA in water, 250 x 250  $\mu$  field of view).

Fig. 3 is an action spectrum for changes in the native fluorescence of skin excited at 335 nm. This fluorescence has been found to be associated with pepsin digestible collagen cross links. The results presented are from hairless mouse skin (n=8) and each animal was exposed (single exposure) on different skin sites on its back at 7 J/cm<sup>2</sup> for each wavelength. Illumination was provided by a tunable OPO laser (Optical Parametric Oscillator).

## DETAILED DESCRIPTION OF THE INVENTION

The features and other details of the invention will now be more particularly described and pointed out in the claims. It will be understood that the particular embodiments of the invention are shown by way of illustration and not as limitations of the invention. The principle features of this invention can be employed in various embodiments without departing from the scope of the invention.

In one aspect, the present invention is directed to methods for treating acne. The methods include exposing the subject afflicted with acne to ultraviolet light having a wavelength between about 320 to about 350 nm, such that the acne is treated, e.g., inhibited, diminished, eradicated or prevented. In a preferred embodiment, the wavelength is 335 nm and is emitted by a nitrogen laser, a third harmonic of a NdYAG laser, a tunable OPO laser (Optical Parametric Oscillator), or a properly filtered mercury lamp or continuous wave lamp. Treatments can be administered over a several week period, where the subject is exposed to sequential doses of ultraviolet light to obtain beneficial effects, e.g., a reduction or elimination of the acne, e.g., eradication or diminishment of the bacteria responsible for acne, e.g., *Propionibacterium acnes*.

The terms "treating" or "treatment" are intended to include eradication of, inhibition of, prevention of and/or diminishment of disease states or conditions



associated with pore blockage by sebum or lipids produced by the sebaceous glands. In a preferred embodiment, the occurrence of acne, measured by reduction of blackheads, whiteheads and/or the amount of sebaceous glands or size of sebaceous glands in a subject, is diminished, preferably by at least 30%, more preferably by at least 50%,  
5 even more preferably by at least 90%, and most preferably by at least 99%.

Preferably, the occurrence of acne or a related condition is eliminated from the subject.

The term "subject" is intended to include living organisms susceptible to conditions or diseases caused or contributed to by overstimulation or production of sebum from sebaceous glands. Examples of subjects include humans, dogs, cats, cows,  
10 goats, and mice. The term subject is further intended to include transgenic species.

The term "acne" is art recognized and is intended to include acne vulgaris and acne rosacea. The term encompasses the condition(s) associated with the complex interactions between hormones and bacteria in the pilosebaceous unit which often result in comedones. Acne vulgaris is the most common skin disease seen in dermatologic  
15 practice which affects millions of people in the United States. Abnormal keratin production with obstruction of the follicular opening, increased production of sebum (lipids secreted by the androgen-sensitive sebaceous glands), proliferation of *Propionibacterium acnes* (anerobic follicular diphtheroids), follicular rupture and follicular mites (demodex) are commonly associated with acne.

20 In acne vulgaris, rupture of a follicle is the event which stimulates inflammation to form a "pimple," including accumulation of pus to form a "whitehead."

"Blackheads" (an open comedo) consist of a plugged sebaceous follicle which contains melanin or melanin-oxidized substances which absorb light.

25 There is no doubt that acne is related to the presence of hyperactive sebaceous glands, no matter what the cause. Therefore, a method which results in diminution of sebaceous gland activity, might be a first necessary step in the development of successful treatment for acne. The present invention is directed to diminishing sebaceous gland activity and/or reduction or destruction of the sebaceous gland.

30 In another aspect, the present invention is also directed to methods for preventing acne. The methods include exposing the subject afflicted with acne to ultraviolet light having a wavelength between about 320 nm to about 350 nm, such that

acne is prevented. Therefore, the methods of the invention can be used prophylactically to reduce or eliminate the possibility of having follicle openings plugged with sebum, dirt and/or lipids.

5 In one embodiment, ultraviolet wavelengths useful in the invention are between about 320 nm to about 360 nm, between about 325 nm to about 345 nm, preferably between about 330 to about 340 nm, more preferably between about 332 and about 337 nm, and most preferred at 335 nm.

10 In yet another aspect, the present invention is also directed to methods for reducing the amount or size of sebaceous glands in a subject. The methods include exposing the subject to ultraviolet light having a wavelength between about 320 and 350 nm, such that the amount or size of sebaceous glands in the subject are reduced. The reduction of sebaceous glands in either size or number can be transitory, lasting several days to several weeks, or, more preferably, can be permanent.

15 The term "sebaceous gland" is art recognized and is a component of the pilosebaceous unit. Sebaceous glands are located throughout the body, especially on the face and upper trunk, and produce sebum, a lipid-rich secretion that coats the hair and the epidermal surface. Sebaceous glands are involved in the pathogenesis of several diseases, the most frequent one being acne vulgaris. Acne is a multi factorial disease characterized by the occlusion of follicles by plugs made out of abnormally shed  
20 keratinocytes of the infundibulum (upper portion of the hair follicle) in the setting of excess sebum production by hyperactive sebaceous glands. An advantage of the present invention is that the treatment can permanently alter the sebaceous gland, e.g., eliminate or reduce the number or size of sebaceous glands, rendering the sebaceous gland no longer susceptible to pore pluggage without the side effects of topical or oral  
25 drugs.

In still another aspect, the present invention is further directed to methods for treating disease states or conditions which cause or are associated with the generation of excess of sebum in sebaceous glands. The invention is also directed to methods for treating disease states or conditions which cause or are associated with the occlusion of  
30 sebaceous glands with accumulation of sebum and fatty acids produced by bacteria through lipase breakdown of lipids. These methods include exposing the subject to

ultraviolet light having a wavelength between about 320 and 360 nm, such that the buildup of sebum and/or lipids in the sebaceous glands of the pilosebaceous units of the subject are reduced.

5 The phrase "disease state or condition" is intended to include those sebaceous gland disorders which can be treated by a narrow range of ultraviolet light, e.g., between about 320 and 360, between about 320 and about 350 nm, preferably between about 325 nm and about 345 nm, more preferably between about 330 nm and about 340 nm, even more preferably between about 332 nm and about 337 nm, and most preferably about 335 nm. Examples of disease states or conditions which can be treated  
10 by the methods of the invention include sebaceous gland hyperplasia, acne vulgaris and acne rosacea. Of particular importance is the treatment of acne by the methods of the invention.

Typically the treatment of the subject with ultraviolet light at the preferred wavelengths of the invention is conducted such that the ultraviolet light has a fluence of  
15 between about 1 J/cm<sup>2</sup> and about 5 J/cm<sup>2</sup>, preferably about 5 J/cm<sup>2</sup>. In one embodiment, the treatment is performed between about 0.1 and about 0.5 of the minimum erythema dosage level. Typical fluence rates, for lasers, are between about 5 and 25 millijoules/pulse, more preferably between about 7 and 20 millijoules/pulse, even more preferably between about 10 and 15 millijoules/pulse, and most preferably  
20 about 10 millijoules per pulse at about a 10 nanosecond duration, thereby producing approximately between about 2 and about 2 megawatts. Typical fluence rates in non-laser applications are between about 2 and 50 milliwatts/cm<sup>2</sup>.

In general the methods of the invention are performed over a period of time, usually several weeks, where a treatment is undertaken on a daily, every second or  
25 third day, or weekly basis. Ideally, a subject would undergo treatments 3 to 4 times a week for 3 to 4 weeks, with a individual exposures of about 5 J/cm<sup>2</sup> of the preferred ultraviolet wavelengths of the invention.

One skilled in the art would be able to choose an energy source which would produce a narrow ultraviolet wavelength between about 320 and about 350 nm, between  
30 about 325 and about 345 nm, between about 330 and about 340 nm, between about 332 and about 337 nm and specifically 335 nm. Such energy sources include fluorescent

lamps with an internal fluorescent coating that emits only in these particular wavelengths, nitrogen lasers, the third harmonic of NdYAG lasers, or a dye laser whose output is scanned over the area of the skin which requires treatment. The device can be in the shape of a flat panel for chest or back exposure, or it can have the shape of a semicircle for exposing the face.

Sunlight is composed of a broad spectrum of energy wavelengths, including ultraviolet light referred to as UVA and UVB. Although it is generally believed that sunlight generally ameliorates acne, several studies have actually shown that sunlight can increase the occurrence of acne or aggravate the condition. Gfesser and Worret (*Int. J. Derm.* 35, 116 (1996)) studied the effects of sun light and seasonal changes on acne. They concluded that exposure to sun light may have beneficial psychological effects but did not find that sunlight, in general, eliminated acne and, in certain individuals, increased outbreaks of acne. Similarly, Mills et al. (*Brit. J. Derm.* 98, 145 (1978)) found that treatment of individuals with ultraviolet light between 280 and 320 nm actually caused acne to worsen and increased the creation of comedones. Sigurdsson et al. (*Dermatology* 194, 256 (1997)) studied the effects of "full spectrum" light treatment on acne vulgaris above 360 nm and concluded that visible light was a moderately effective treatment for acne. Therefore, it was surprising to unexpectedly find that a narrow band of ultraviolet light would have beneficial effects on the treatment of skin disorders such as acne.

It has been unexpectedly discovered that certain wavelengths of ultraviolet light, e.g., between about 320 to about 350 nm, are capable of producing biological effects in a wavelength specific way. The changes are produced in a fashion similar to selective photothermolysis, i.e., there appears to be a target organelle or appendix within the skin for each wavelength. In particular, it was discovered that multiple exposures to 335 nm light result in significant decrease in the frequency of appearance of sebaceous glands, e.g., in the skin of hairless mice. These wavelength specific biological changes can vary depending on whether continuous light (cw) or a pulsed laser is used.

The present invention is directed to accomplishing these goals by manipulating radiation at the wavelengths where fluorophores present in skin absorb. Selection of the appropriate energy, e.g., ultraviolet wavelength, produces a biological response, in

addition to producing changes in the native fluorescence of the skin. In particular, exposure of hairless mice skin to multiple suberythemogenic doses of 335 nm ( $\pm 10$  nm) produces significant reduction in the frequency of appearance of sebaceous glands as well as subtle changes in the collagen matrix. The reduction of the sebaceous gland density has been confirmed with routine histology as well as *in vivo* by laser scanning confocal microscopy (Figs. 1 and 2).

Previous studies have shown that 335 nm radiation is effective in reducing the native fluorescence of hairless mouse skin as well as the fluorescence of human skin. The fluence necessary to produce a twofold decrease is of the order of 1 J/cm<sup>2</sup>. Unexpectedly, it was discussed that treatment of skin with exposure to ultraviolet light between the range of about 320 nm to about 350 nm, preferably between about 325 nm to about 345 nm, most preferably at 335 nm, reduced sebaceous gland activity and rendered and/or destroyed the sebaceous unit. For example, assuming a typical solar UVA radiation fluence rate of 4 mW/cm<sup>2</sup> (summer, no direct sun exposure), there is approximately 1 J/cm<sup>2</sup> of solar UVA corresponding to a 5 minute exposure. Changes in fluorescence are produced in a wavelength specific way i.e., the changes produced at 335 nm are produced with 5 times smaller dose than those at 360 nm (Fig. 3).

The mechanism of action for the depletion of sebaceous glands is not well understood because there is not a well characterized absorber in the pilosebaceous unit that absorbs light in this wavelength range. It is considered that a reduction in the number or size of sebaceous units in the hairless mouse would correspond to a similar response in the case of human skin. One consideration is that human skin is thicker with sebaceous glands located further in, which means that they would receive a reduced fluence rate, assuming that the same chromophores are present in both species. However, results on hairless mice indicate the applicability to human skin and the treatment of acne.

Both a continuous wave source as well as an optical parametric oscillator (OPO laser) have been utilized to treat skin. The skin response to the two light sources using similar fluences and fluence rates were different. The laser source (with 10 ns pulses) produced a greater level of inflammatory infiltrate without a clinical erythema response.

It is considered that the laser is as effective in reducing the frequency of appearance of sebaceous glands at substantially reduced fluences.

The experiments presented below investigate the details of the interaction of 335 nm radiation on the sebaceous glands of the hairless mouse demonstrate a precise dose response for the laser versus the cw narrow band source, and show the effect of 335 nm radiation on human skin *in vivo*.

### Experimental Methods

1. **Dose Dependent Animal Studies.** The dose dependence of the reduction in sebaceous glands was tested on 12 mice (rhino mouse model). Sites on the back of each animal were tattooed and then received daily exposures at 0.05, 0.1, 0.2, 0.4, 0.8 MED of 335 nm radiation. The animals were exposed on one side of their back to cw radiation and on the other side with short pulse laser radiation (10 ns). The animals were followed up daily by confocal microscopy *in vivo* and biopsies were taken at time points after changes in the number of sebaceous glands were documented by confocal microscopy. Exposures were continued for up to 4 weeks on the sites that experienced no adverse effects (erythema, edema, scaling). Biopsies were taken from selected sites at the end of one month of exposures and the rest of the animals were followed up weekly at first and biweekly thereafter for up to 2 months to determine the rate of recovery. Frozen sections were obtained from the biopsied sites for autofluorescence microscopy analysis.

2. **Dose Dependence Human Studies.** Skin sites (2.5 cm in diameter) of the upper back of 12 normal human volunteers with mild to moderate acne will be exposed to 0.1, 0.25 and 0.5 of an MED (minimum erythema dose) of 335 nm radiation, three times a week. The MED will be first determined for each volunteer. Confocal microscopy images will be obtained from control and exposed sites on a weekly basis. At the end of the treatment period 3 nm biopsies will be taken from treated and control sites. Histological staining will include H&E as well as colloidal iron for evaluating changes induced to the structural matrix. The

exposed sites will be followed up for up to 2 months to evaluate recovery of the sebaceous glands.

- 5           **3. Chromophore Identification.** Skin from hairless mice and from humans will be obtained for fluorescence microscopy. Frozen and fresh sections will be prepared and fluorescence spectroscopy will be performed on the frozen and the fresh sections to identify the regions of the dermis where the 335 nm fluorescence originates from. High power pulsed laser radiation at 335 nm will then be used to determine whether the tissue site that absorbs at 335 nm, in order to produce fluorescence is also altered by the laser pulse or whether there are other organelles that are susceptible as well.
- 10

One of ordinary skill in the art will appreciate further features and advantages of the invention based on the above-described embodiments. Accordingly, the invention is not to be limited by what has been particularly shown and described, except as indicated by the appended claims. All publications and references cited herein, including those in the background, are expressly incorporated herein by reference in their entirety.

15

What is claimed is:

1. A method for treating acne, comprising exposing a subject afflicted with acne to ultraviolet light having a wavelength between about 320 to about 360 nm, such that said acne is treated.

5           2. The method of claim 1, wherein said wavelength is between about 325 to about 345 nm.

3. The method of claim 1, wherein said wavelength is between about 330 to about 340 nm.

10

4. The method of claim 1, wherein said wavelength is between 332 and 337 nm.

5. The method of claim 1, wherein said wavelength is about 335 nm.

15

6. The method of claim 1, wherein said ultraviolet light is produced by a nitrogen laser.

7. The method of claim 1, wherein said ultraviolet light is produced by a third harmonic of a NdYAG laser.

20

8. A method of claim 1, wherein said ultraviolet light has a fluence of between about 1 J/cm<sup>2</sup> and about 5 J/cm<sup>2</sup>.

9. The method of claim 1, wherein said treatment is performed at between about 0.1 to about 0.5 minimum erythema dose.

25

10. The method of claim 1, wherein said treatment is conducted over multiple exposure periods.

30



11. A method for preventing acne, comprising exposing a subject afflicted with acne to ultraviolet light having a wavelength between about 320 nm to about 360 nm, such that acne is prevented.

5           12. The method of claim 11, wherein said wavelength is between about 325 to about 345 nm.

10           13. The method of claim 11, wherein said wavelength is between about 330 to about 340 nm.

          14. The method of claim 11, wherein said wavelength is between 332 and 337 nm.

15           15. The method of claim 11, wherein said wavelength is about 335 nm.

          16. The method of claim 11, wherein said ultraviolet light is produced by a nitrogen laser.

20           17. The method of claim 11, wherein said ultraviolet light is produced by a third harmonic of a NdYAG laser.

          18. A method of claim 11, wherein said ultraviolet light has a fluence of between about 1 J/cm<sup>2</sup> and about 5 J/cm<sup>2</sup>.

25           19. The method of claim 21, wherein said treatment is performed at between about 0.1 to about 0.5 minimum erythema dose.

30           20. The method of claim 21, wherein said treatment is conducted over multiple exposure periods.

21. A method for reducing the amount or size of sebaceous glands in a subject, comprising exposing a subject to ultraviolet light having a wavelength between about 320 and 360 nm, such that the amount or size of sebaceous glands in said subject are reduced.

5

22. The method of claim 21, wherein said wavelength is between about 325 to about 345 nm.

10

23. The method of claim 21, wherein said wavelength is between about 330 to about 340 nm.

24. The method of claim 21, wherein said wavelength is between 332 and 337 nm.

15

25. The method of claim 21, wherein said wavelength is about 335 nm.

26. The method of claim 21, wherein said ultraviolet light is produced by a nitrogen laser.

20

27. The method of claim 21, wherein said ultraviolet light is produced by a third harmonic of a NdYAG laser.

28. A method of claim 21, wherein said ultraviolet light has a fluence of between about 1 J/cm<sup>2</sup> and about 5 J/cm<sup>2</sup>.

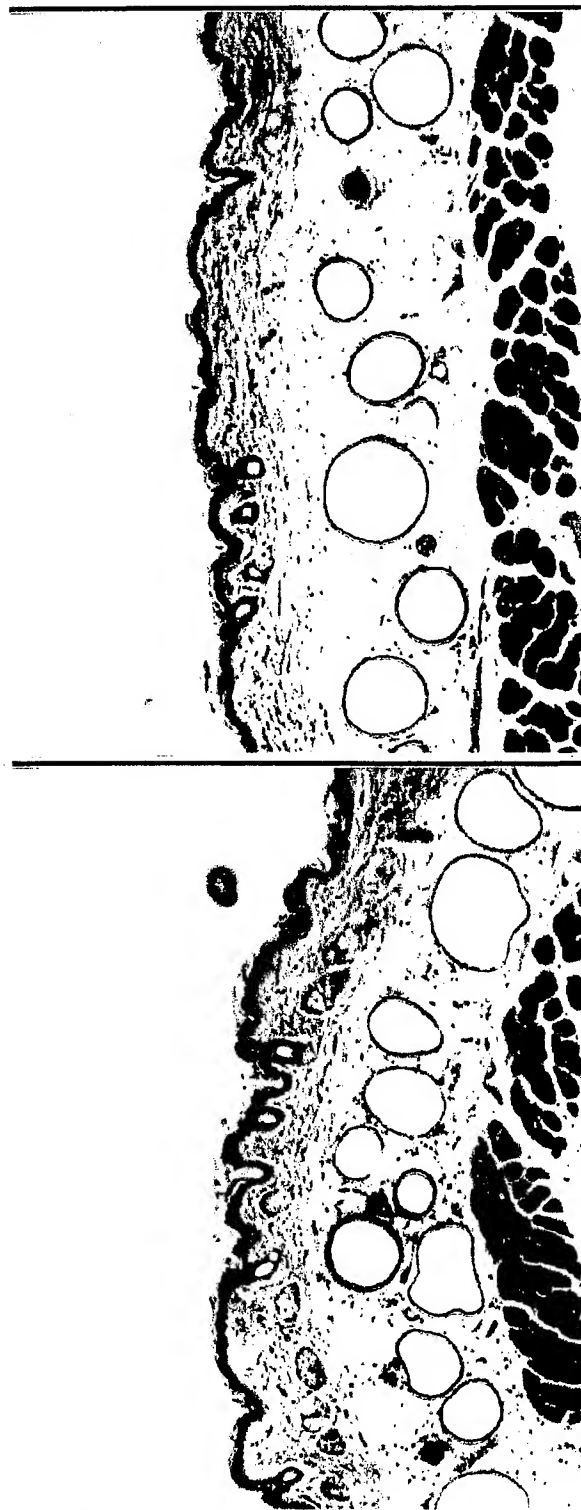
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29. The method of claim 21, wherein said treatment is performed at between about 0.1 to about 0.5 minimum erythema dose.

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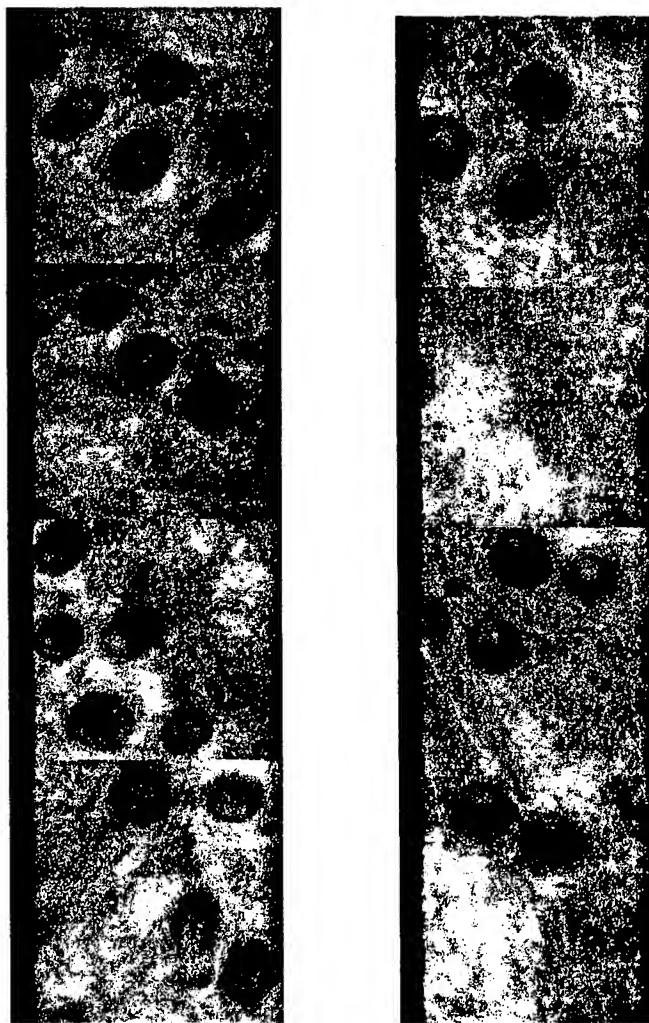
30. The method of claim 21, wherein said treatment is conducted over multiple exposure periods.

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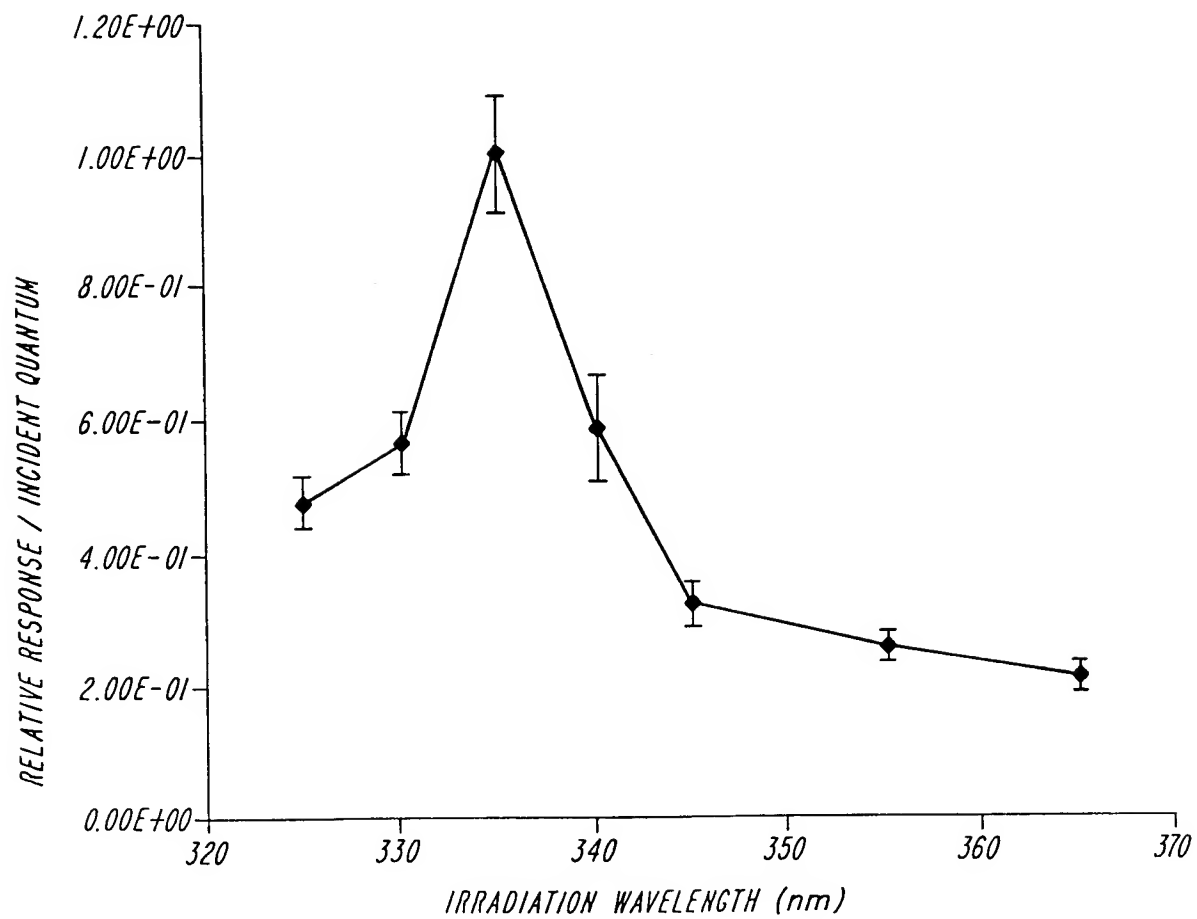
*FIG. 1*

2 / 3



*FIG. 2*

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**FIG. 3**

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61N5/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61N A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
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- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
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Date of the actual completion of the international search

1 August 2000

Date of mailing of the international search report

07/08/2000

Name and mailing address of the ISA

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

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(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
30 November 2000 (30.11.2000)

PCT

(10) International Publication Number  
**WO 00/71045 A1**

(51) International Patent Classification<sup>7</sup>: A61B 18/20

(21) International Application Number: PCT/IL99/00279

(22) International Filing Date: 25 May 1999 (25.05.1999)

(25) Filing Language: English

(26) Publication Language: English

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ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

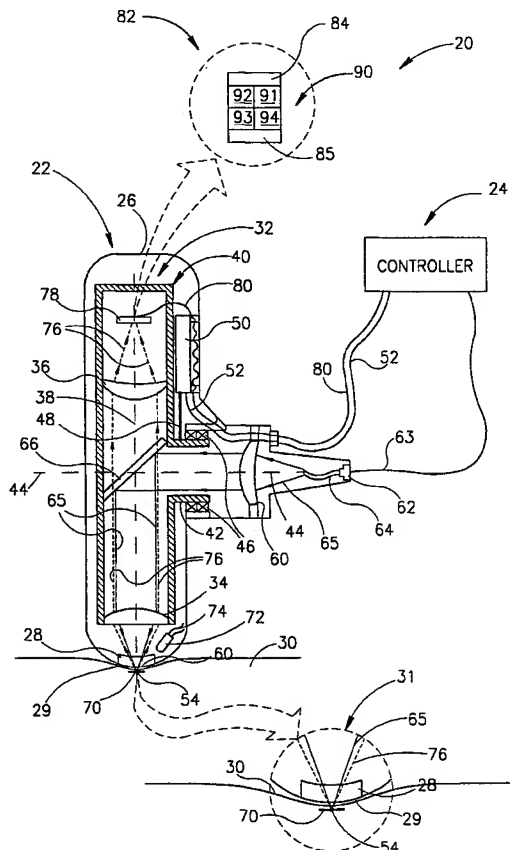
Published:

— With international search report.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: LASER FOR SKIN TREATMENT

(57) Abstract: A laser system for treating features on the skin of a patient with laser light comprising: an imaging subsystem that locates features on the skin to be treated; a laser; laser optics that focuses light from the laser onto a feature located by the imaging subsystem; and a controller that when a feature is located, controls the laser to radiate a pulse of laser light that is focused by the laser optics to a spot localized about the feature.



WO 00/71045 A1



**LASER FOR SKIN TREATMENT****FIELD OF THE INVENTION**

The invention relates to laser devices and especially to laser devices used for cosmetic and surgical treatment of the skin.

**5 BACKGROUND OF THE INVENTION**

The use of lasers in corrective and cosmetic surgery procedures is well known. In these procedures light from a laser comprised in an appropriate mechanical-optical system causes a desired cosmetic or surgical change in a region of tissue by delivering to the region an amount of energy sufficient to effect the change. A common problem often encountered in these  
10 procedures is to deliver the energy to the region, hereinafter referred to as a "target", without delivering energy to tissue surrounding the region that might damage the surrounding tissue. Many prior art medical laser systems do not solve this problem satisfactorily and often deliver substantial amounts of unwanted and unneeded energy to tissue surrounding a target that they irradiate.

15 For example, laser light is often used to depilate skin by cauterizing follicles of hair to be removed from the skin. Most prior art laser depilators irradiate areas of skin much larger than the area of skin occupied by a hair follicle. As a result, most of the laser energy these depilators radiate is wasted. A major portion of the laser energy is incident on hairless areas of skin and only a small portion is incident on targets (*i.e.* hair follicles) on the skin and used to  
20 remove hair. Since the prior art laser depilators are energy inefficient, they generally require relatively powerful lasers that illuminate skin being treated with a high energy density of laser light. This energy density when incident on hairless regions of skin can cause thermal damage to these areas.

For example, typically 20 milliJoules (mJ) of energy are required to cauterize a hair  
25 follicle and a typical hair follicle occupies an area of skin approximately  $3 \times 10^{-4} \text{ cm}^2$ . An energy density of about  $60 \text{ J/cm}^2$  therefore is generally required to cauterize hair follicles. Many prior art laser depilators irradiate an area of skin on the order of  $1 \text{ cm}^2$  with a pulse of laser energy lasting about a millisecond or a fraction of a millisecond to depilate an area of skin. A Laser in one of these systems must therefore provide a peak power output of about  
30 60,000 watts.

**SUMMARY OF THE INVENTION**

An aspect of some preferred embodiments of the present invention relates to providing a laser system for medical/cosmetic treatment of skin, such as for hair removal, coagulation of

varicose veins and the removal of skin tumors, that minimizes the amount of laser energy incident on tissue surrounding targets that the system irradiates.

According to an aspect of some preferred embodiments of the present invention, the laser system comprises an optical imaging subsystem that scans the skin of a patient being  
5 treated and identifies and locates targets for treatment in the area.

Preferably, the optical imaging subsystem comprises a microscope that collects light from an object that it images and focuses the collected light to form a magnified image of the object on a photosensitive surface. The skin being treated is optically scanned by positioning the microscope's objective lens close to the skin and moving the microscope so as to image  
10 different regions of the skin onto the photosensitive surface. Image data from the photosensitive surface characteristic of an imaged region are transmitted to circuitry that analyzes the data to determine if a target is located in the imaged region. Preferably, an imaged region is determined to have a target if a portion of the image exhibits characteristics typical of a target and the portion corresponds to an area of the skin substantially centered at the focal  
15 point of the microscope.

Preferably, the laser system comprises a light source that illuminates regions of the skin imaged by the microscope with light having a spectrum that enhances the contrast between targets and clear skin devoid of targets.

For example, assume that the skin is being depilated, that targets on the skin to be  
20 searched for are hair follicles and that the skin is illuminated with light for which hair follicles have relatively low reflectance compared to the reflectance of clear skin. Since the hair follicles are expected to reflect less light than clear skin, the imaging subsystem will search for relatively dark areas on the skin having a size characteristic of hair follicles. If such a relatively dark area is found in an imaged region of the skin and the dark area is substantially centered at  
25 the focal point of the microscope, the imaged region is determined to have a target for irradiation.

According to an aspect of some preferred embodiments of the present invention the laser system comprises a laser and associated optical elements that are controllable to irradiate with laser energy substantially only targets identified by the imaging subsystem.

The optical elements preferably focus light from the laser to a spot centered at the focal  
30 point of the microscope. The spot size is preferably determined with reference to the sizes of targets to be treated with the system. Preferably, the spot size is determined to be a small multiple of an expected characteristic size of the targets. In some preferred embodiments of the

present invention it is less than three times the size of the feature. Preferably, the spot size is smaller than twice the characteristic size of the feature. More preferably the spot size is less than 1.5 times the characteristic size of the feature. Most preferably, the spot size is greater than about 1.2 times the characteristic size of the feature. For example, if the laser system is being used to depilate skin, the spot size is preferably determined to be a small multiple of a characteristic size of a hair follicle. A characteristic size of a hair follicle might be an average size of a hair follicle or a hair follicle size that is greater than the size of 95% of the hair follicles. If the laser unit is being used to eradicate small tumors, a characteristic size is a suitable expected size of the tumors.

The laser is preferably turned on and off by a controller. During the scan of a treated area of skin the laser is normally off. However, when an imaged region of the skin is determined to have a target located within a "spot size" of the microscope's focal point, the controller turns the laser on to deliver a pulse of laser light to a spot centered at the focal point and thereby to the target. Preferably, the controller determines the energy in the pulse by controlling the pulse width and/or the intensity of light in the light pulse.

The scan speed of the imaging subsystem is preferably sufficiently slow so that the imaging system remains focused substantially on a same region of skin during the time it takes to determine whether an imaged region has a target and energize the laser. Furthermore, as noted above, the spot size to which a light pulse is focused, is preferably slightly larger than a target defined by a feature of the skin that is to be irradiated. Therefore, the energy in laser light pulses radiated by the laser system is substantially restricted to areas of targets or areas immediately surrounding targets. For example the energy in a laser light pulse might be restricted to an area having a diameter 1.5 or 2 times the diameter of the area of a target that the light pulse irradiates.

Thus, with a laser system in accordance with a preferred embodiment of the present invention, laser energy used to effect cosmetic or surgical changes in the skin of a patient is substantially restricted to only those areas of the skin that require treatment. Little of the energy radiated by the system is incident on skin areas where it is not needed.

A laser system in accordance with a preferred embodiment of the present invention therefore uses laser energy efficiently and can generally treat features on a patient's skin using a laser having substantially lower power output than lasers used in comparative prior art systems. For example in a laser depilator, in accordance with a preferred embodiment of the present invention, laser energy is focused to a spot size of about  $3 \times 10^{-4} \text{ cm}^2$ . Laser energy is

delivered to cauterize a hair follicle in a laser pulse having a pulse width of about 2 milliseconds. Assuming 20 mJ of energy is needed to cauterize the hair follicle a laser that provides the pulse has to supply a peak power of about 10 watts. The laser depilator, in accordance with a preferred embodiment of the present invention, uses a laser having a peak power output about one thousandth that used in many prior art laser depilators.

Whereas in the example given above a laser providing a peak power of ten watts is used, a laser that provides different peak power output is useable in a laser system in accordance with a preferred embodiment of the present invention. Preferably the peak power of the laser is less than 100 watts. More preferably the peak power is less than 50 watts. Most preferably the peak power is less than 30 watts.

According to an aspect of some preferred embodiments of the present invention the microscope, photosensitive surface and laser are mounted in a hand unit. To treat a patient an operator of the laser system holds the hand unit with the microscope objective lens close to and facing the patient's skin. The operator moves the hand unit substantially parallel to the skin to scan an area of the skin for targets. As targets are identified, they are irradiated with laser light from the laser.

In accordance with an aspect of some preferred embodiments of the present invention the microscope is preferably mounted in the hand unit so that it is rotatable about an axis of rotation that is perpendicular to the microscope's optic axis and fixed with respect to the hand unit. The microscope is coupled to a motor or actuator in the hand unit that rotates the microscope about the axis back and forth through a predetermined angle. The focal point of the microscope therefore moves back and forth, near to or on the surface of the patient's skin, along a direction perpendicular to the axis of rotation of the microscope. The operator preferably moves the hand unit along the skin in a direction substantially parallel to the axis of rotation. As a result of the back and forth motion of the focal point of the microscope and the motion of the hand unit, the imaging system scans a ribbon shaped area on the patient's skin and target regions in the area are identified and irradiated.

There is thus provided, in accordance with a preferred embodiment of the invention, a laser system for treating features on the skin of a patient with laser light comprising:

- an imaging subsystem that locates features on the skin to be treated;
- a laser;

- laser optics that focuses light from the laser onto a feature located by the imaging subsystem; and

a controller, that when a feature is located, controls the laser to radiate a pulse of laser light that is focused by the laser optics to a spot localized about the feature.

Preferably, the system includes a light source that illuminates regions imaged by the imaging optics with light for which the features to be treated have a reflectance different from that of clear skin so that a feature to be treated appears as a contrasted sub-region of an imaged region of the skin.

Preferably, the spectrum of the light radiated by the light source is tunable.

Preferably, the spot to which the laser is focused has an area substantially equal to an area characteristic of the size distribution of areas occupied on the skin by features to be treated, multiplied by a factor greater than one. Preferably, the factor is less than 2 or 1.5. Preferably, the factor is greater than about 1.2.

Preferably, the controller controls the laser to radiate a pulse of light only if a located feature occupies an area on the skin consistent with the size distribution of areas occupied on the skin by features to be treated.

In a preferred embodiment of the invention, the imaging subsystem scans an area of the skin and during scanning automatically locates features on the area to be treated.

In a preferred embodiment of the invention, the imaging subsystem comprises:

at least one photosensitive surface that generates signals responsive to an image formed thereon; and

imaging optics that images light that it collects on the at least one photosensitive surface;

wherein, to scan the area, the imaging optics are moved relative to the skin so as to image regions in the scanned area onto the at least one photosensitive surface.

Preferably, the imaging optics has a focal point and the spot to which the pulse of laser light is focused is centered at the imaging optics focal point.

Preferably, the controller controls the laser to radiate a pulse of light only if a feature to be treated is determined to lie substantially within an area centered at the imaging optics focal point having a size substantially equal to the size of the spot to which the laser pulse is focused.

Preferably, the system includes circuitry that receives signals generated by the at least one photosurface responsive to an imaged region of the skin and processes the signals to locate contrasted sub-regions in the imaged region to locate features to be treated.

Preferably, the at least one photosensitive surface comprises a single photosensitive surface. Preferably, the photosensitive surface comprises a quadrature detector. Preferably

signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is substantially centered within the spot to which the laser pulse is focused. Preferably, signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is larger than a predetermined minimum size consistent with the size distribution of areas occupied on the skin by features to be treated.

In a preferred embodiment of the invention, the photosensitive surface additionally comprises at least two photodetectors located adjacent to opposite sides of the quadrature detector. Preferably, if any of the photodetectors adjacent to sides of the quadrature detector generates a signal responsive to a contrasted sub-region imaged on the photosensitive surface, a portion of the sub-region is determined to lie outside the spot to which the laser pulse is focused and the laser is not energized.

In an alternative preferred embodiment of the invention, the at least one photosurface comprises a first and a second photosensitive surface. Preferably, the first photosensitive surfaces comprises a quadrature detector. Preferably, signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is substantially centered within the spot to which the laser pulse is focused. Preferably, signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is larger than a predetermined minimum size consistent with the size distribution of areas occupied on the skin by features to be treated.

In a preferred embodiment of the invention, the second detector comprises a photodetector having a mask that blocks light from impinging on an area located at its center. Preferably, the photosensitive surface generates signals responsive to a contrasted sub-region imaged on the photosensitive surface, a portion of the sub-region is determined to lie outside of the spot to which the laser pulse is focused and the laser is not energized.

In a preferred embodiment of the invention, the imaging optics comprises an objective lens system having a focal point that collects light from regions imaged by the imaging subsystem and wherein the focal point of the imaging optics is the focal point of the objective lens system. Preferably, the laser optics comprises an ocular lens system that receives light collected by the objective lens system and images the received light on the at least one photosensitive surface. Preferably, the objective lens system is rotatable about an axis of rotation that intersects the optic axis of the objective lens system. Preferably, the laser optics comprises a collimating lens system that receives light radiated by the laser, which it collimates

and transmits parallel to the axis of rotation. Preferably, the imaging optics comprises a reflector that reflects the collimated laser light towards the objective lens system along a direction parallel to the optic axis of the objective lens system so that the laser light is focused to a spot at the focal point of the objective lens system.

- 5 In a preferred embodiment of the invention, the reflector is a beam splitter. Preferably, the ocular lens system and the at least one photosensitive surface are positioned on a side of the reflector opposite to the side of the reflector on which the objective lens system is located.

In an alternative preferred embodiment of the invention, the reflector is a mirror. Preferably, the ocular optics and the at least one photosensitive surface are stationary with  
10 respect to the axis of rotation. Preferably, the system a beam splitter positioned between the collimating lens and the mirror and wherein light collected by the objective optics is reflected by the mirror along the axis of rotation towards the beam splitter, which reflects some of the collected light incident on it towards the ocular lens system.

In a preferred embodiment of the invention, the system comprises a motor or actuator  
15 that is coupled to the objective lens system and rotates the objective lens system with an oscillatory motion about the axis of rotation, so that the objective focal point moves back and forth along a planar arc having a fixed length.

In a preferred embodiment of the invention, the imaging optics and the at least one photosensitive surface are mounted within a hand held unit. Preferably, the light source is  
20 mounted in or on the hand held unit. Preferably, the laser is mounted within the hand held unit. Preferably, the controller is mounted in the hand held unit. Preferably, the system comprises a power source mounted in the hand held unit.

There is further provided, in accordance with a preferred embodiment of the invention, a method for treating features on the skin of a patient with laser light comprising:

- 25 optically scanning the patient's skin to locate features to be treated; and  
during scanning, when a feature is located, focusing a pulse of laser light energy to a spot that covers substantially completely the feature, which spot has an area substantially equal to an area characteristic of the size distribution of areas occupied on the skin by features to be treated, multiplied by a factor greater than one, preferably, greater than about 1.2 and  
30 preferably less than about 1.5 or 2.

In a preferred embodiment of the invention, the method includes analyzing imaged regions of the skin to locate features to be treated. Preferably, analyzing imaged regions comprises determining whether an imaged region of the skin has a feature having a size

consistent with the size distribution of areas occupied on the skin by features to be treated. Preferably, analyzing imaged regions comprises determining whether an imaged region of the skin has a hair feature to be treated located within a localized region on the skin which is centered at the focal point.

5           There is further provided, in accordance with a preferred embodiment of the invention, a method for depilating a patient's skin using laser light comprising:

          optically scanning the patient's skin to locate hair follicles in regions of the skin to be depilated; and

          during scanning, when a hair follicle is located, cauterizing the hair follicle by focusing  
10   a pulse of laser light energy to a spot that shadows substantially completely the hair follicle, which spot has an area substantially equal to an area characteristic of the size distribution of areas occupied on the skin by hair follicles, multiplied by a factor greater than one, preferably greater than about 1.2, and preferably less than 1.5 or 2.

          In a preferred embodiment of the invention, the method includes analyzing imaged  
15   regions of the skin to locate hair follicles to be treated. Preferably, analyzing imaged regions comprises determining whether an imaged region of the skin has a feature having a size consistent with the size distribution of follicles areas occupied on the skin by features to be treated. Preferably, analyzing imaged regions comprises determining whether an imaged region of the skin has a follicle to be treated located within a localized region on the skin which is  
20   centered at the focal point.

          In a preferred embodiment of the invention, scanning comprises moving an optical imaging system having a focal point over the patients skin to image different regions of the skin. Preferably, moving an optical imaging system comprises moving the focal point close to and along the patient's skin.

25           Preferably, focusing a pulse of laser light energy comprises focusing the energy to a spot centered at the focal point.

          In a preferred embodiment of the invention, the localized region is substantially equal to the size of the spot to which the laser light is focused. Preferably, moving the focal point comprises moving the focal point with an oscillatory motion along a first direction on the skin.  
30   Preferably, the method includes moving the focal point in a second direction substantially perpendicular to the first direction while the focal point is oscillating. Preferably, moving the optical imaging system comprises moving the optical imaging system by hand.



## BRIEF DESCRIPTION OF FIGURES

The invention will be more clearly understood by reference to the following description of preferred embodiments thereof read in conjunction with the figures attached hereto. In the figures identical structures, elements or parts which appear in more than one figure are labeled with the same numeral in all the figures in which they appear. Dimensions of components and features shown in the figures are chosen for convenience and clarity of presentation and are not necessarily shown to scale. The figures are listed below.

Fig. 1A shows schematically a laser system comprising a hand unit shown in cut-away side view, in accordance with a preferred embodiment of the present invention;

Fig. 1B shows a schematic circuit for analyzing images of regions of a patient's skin formed on a photosensitive surface located in the hand unit shown in Fig. 1A, in accordance with a preferred embodiment of the present invention;

Fig. 2 shows schematically the hand unit shown in Fig. 1A in a cut-away front view;

Fig. 3 shows schematically the laser system being used to remove hair from the arm of a patient, in accordance with a preferred embodiment of the present invention; and

Fig. 4 shows schematically a variation of the hand unit shown in Figs. 1 - 3, in accordance with a preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1A schematically shows a laser system 20, in accordance with a preferred embodiment of the present invention, comprising a hand unit 22 and a controller 24. Hand unit 22 is shown in a cutaway cross-section view. It should be noted that whereas controller 24 is shown separate from hand unit 22, in most preferred embodiments, controller 24 is mounted on or inside hand unit 22. In addition, energy to power hand unit 22 may come from an external power supply or preferably from an appropriate portable power supply mounted inside hand unit 22.

Hand unit 20 preferably comprises a housing 26 having a window 28. Window 28 has a surface 29 that is pressed to the skin 30 of a patient. Surface 29 and skin 30 are shown separated by a small distance for clarity of presentation and are shown magnified in an insert 31. Hand unit 20 comprises a microscope 32 mounted inside housing 26. Microscope 32 comprises an objective lens 34, an ocular lens 36 and an optic axis 38. Objective lens 34 and ocular lens 36 are preferably mounted in a microscope housing 40. Whereas microscope 32 is shown comprising only two lenses, a hand unit in accordance with a preferred embodiment

may comprise a microscope having more than two lenses. For example, the ocular and/or the objective may comprise a system of lenses.

Microscope housing 40 preferably has a circularly cylindrical tubular extension 42 having an axis of rotation 44 that preferably intersects optic axis 38 at 90°. Microscope 32 is preferably rotatably mounted to hand unit 22 by mounting tubular extension 42 to a bearing 46 that is fastened to housing 26 of hand unit 22. Bearing 46 preferably enables microscope 32 to be rotated back and forth about axis of rotation 44 but prevents motion of microscope 32 parallel to axis of rotation 44. Preferably microscope 32 is controlled to rotate back and forth about axis 44 with an oscillating motion having predetermined angular amplitude. Preferably the frequency of oscillation is less than 100 HZ. More preferably, the frequency of oscillation is less than 50 Hz. Most preferably the frequency is between 5 and 20 Hz.

Many methods for achieving the oscillatory motion are known in the art and may be used in accordance with preferred embodiments of the present invention for providing such motion to microscope 32. For example, in some preferred embodiments of the present invention a electromotor or piezoelectric micromotor is pressed to the surface of tubular extension 42, and thereby microscope 32, to rotate tubular extension 42 back and forth about axis of rotation 44. In some preferred embodiments of the present invention tubular extension 42 is coupled by an appropriate mechanical drive train to a motor or actuator that rotates tubular extension 42 in an oscillatory motion.

By way of example, in Fig. 1A tubular extension 42 is shown having an arm 48 that is rotated back and forth by a motor 50 in order to oscillate microscope 32. Arm 48 is mechanically coupled to motor 50, using any of many various mechanical configurations (not shown) known in the art, such as a by a crank and crankshaft. Preferably motor 50 is controlled and powered by controller 24 to which motor 50 is connected by an appropriate power and control line 52.

The size of window 28, its relative position with respect to microscope 32 and the amplitude of motion of microscope 32 are preferably such that for each angular position of microscope 32 about axis 44, optic axis 38 passes through window 28. Microscope 32 has a focal point 54, preferably located a short distance below window 28. Focal point 54 is most clearly shown in insert 31. As a result of the oscillating motion of microscope 32, focal point 54 moves back and forth along a circular arc (not shown), which is perpendicular to the plane of Fig. 1A and which lies in a plane perpendicular to axis 44. The projection of focal point 54 on skin 30 oscillates back and forth and scans skin 30 along a substantially straight line

perpendicular to the plane of Fig. 1A (and of course axis 44). Preferably, surface 29 of window 28 is curved in the plane of the arc of motion of focal point 54 so that focal point 54 is substantially a same distance from surface 29 for all points along its arc of motion.

Hand unit 22 preferably comprises a laser 62 and a collimating lens 60 having an optic axis coincident with axis of rotation 44. Laser 62 is turned on and off by controller 24 to which laser 62 is connected via a control line 63. Laser light from laser 62 is preferably piped to collimating lens 60 via a light guide 64. The laser light is represented by lines 65 that have arrows indicating the direction of travel of the laser light. Collimating lens 60 collimates laser light 65 and directs the collimated laser light to a beam splitting mirror 66 located between objective and ocular lenses 34 and 36. Beam splitter 66 directs some of laser light 65 in a direction parallel to optic axis 38 towards objective lens 34, which focuses laser light 65 to a spot 70 (shown in cross section) centered on focal point 54. Spot 70 and its relationship to focal point 54 is most clearly shown in insert 31.

Preferably laser 62 is a laser diode or an array of a plurality of laser diodes. Light guide 64 preferably comprises a fiber optic bundle. Preferably, laser 62 and light guide 64 are matched so that their throughput is such that spot 70 has a size slightly larger than a characteristic size of a target being treated with laser system 20. (The throughput of the combination of laser 62 and light guide 64 is the product of the cross sectional area of light guide 64 and the angular divergence of laser light exiting the output end of light guide 64.) For example, assume that laser system 20 is being used to remove hair from skin 30 by cauterizing hair follicles with laser energy. Hair follicles have an average diameter of about 200 microns. Therefore, the throughput of laser 62 and light guide 64 is preferably determined so that spot size 70 has a diameter of about 250 microns. This choice for spot size assures efficient cauterization of hair follicles having a diameter of 200 microns without irradiation of large areas of skin 30 surrounding hair follicles that are cauterized.

Hand unit 22 preferably comprises a light source 72 that radiates light through window 28 to illuminate regions of skin 30 located in the vicinity of focal point 54. In some preferred embodiments of the present invention light source 72 comprises a LED or a low powered laser having a spectrum that enhances contrast between features to be irradiated and clear skin.

Preferably, light source 72 comprises a white light source (not shown) that radiates white light onto a preferably adjustable spectrometer (not shown). The adjustable spectrometer, comprising an appropriate diffraction grating or prism, determines the spectral distribution of light from the white light source that is radiated by light source 72 to illuminate skin 30. Light

source 72 is preferably connected to controller 24 by an appropriate control line 74 (only part of which is shown). Preferably, controller 24 controls the spectrometer so that light source 72 radiates light through window 28 that has a spectral distribution which enhances contrast between features of skin 30 to be treated and skin tissue that is free of the features to be treated.

- 5 For example, if skin 30 is to be depilated, preferably skin 30 is first shaved and light source 72 is controlled to illuminate skin 30 with light having a spectral distribution that enhances the contrast between hair follicles of the shaved hairs and hairless skin.

Objective lens 34 collects light from light source 72 that is reflected by a region of skin 32 substantially centered at focal point 54 and directs the collected light, towards ocular lens 10 36. The reflected light is represented by dashed lines 76, which have arrows to indicate the direction of travel of the reflected light. Some of light 76 is transmitted by beam splitter 66 to ocular lens 36, which focuses light 74 to form an image of the region on a photosensitive surface 78.

Photosensitive surface 78 generates signals responsive to the image and the signals are 15 preferably transmitted to controller 24 via a data line 80. Controller 24 comprises circuitry that analyzes the signals to determine if a feature to be treated with laser light is imaged on photosensitive surface 78. If such a feature is found and is localized within an area centered on focal point 54 that has a size substantially equal to the size of spot 70, the region is determined to have a target. For example, if hair follicles are being treated, controller 24 “searches” for a 20 localized dark or light (depending upon the spectrum of light from light source 72) area set against a bright or dark background respectively that has a size characteristic of a hair follicle. If such an area is found and it is substantially localized within an area centered at focal point 54 having the size and shape of spot 70 it is determined to be a target.

Different types of photosensitive surfaces known in the art are useable as photosensitive 25 surface 78. For example, in some preferred embodiments of the present invention photosensitive surface 78 comprises a pixelated photosensitive surface such as a CCD camera. In these embodiments a relatively detailed image of a region centered on the focal point is acquired and analyzed. In other more preferred embodiments of the present invention photosensitive surface 78 comprises a relatively small number of photodetectors in an array 30 appropriate for determining whether a feature is a target or not.

A version of photosensitive surface 78 based on quadrature detection is shown in insert 82. Photosensitive surface 78 preferably comprises photodetectors 84 and 85 and a quadrature detector 90 comprising photodetectors 91, 92, 93 and 94 and having a center point. Axis 38

intersects photosensitive surface 78 at its center point. When a feature that might represent a feature to be treated with laser light is imaged on photosensitive surface 78, signals from photodetectors 91, 92, 93 and 94 are processed using algorithms known in the art to estimate the location of the feature with respect to focal point 54. Signals from photodetectors 84 and 85 are used to determine if the imaged feature occupies an area on the skin greater than a predetermined maximum area. If the image of the feature on photosensitive surface 78 simultaneously stimulates either of photodetectors 84 and 85, the feature is determined by controller 24 to be outside the area of quadrature detector 90 or have an area greater than the maximum area. If the feature is determined to be smaller than the maximum area (*i.e.* neither of photodetectors 84 and 85 is stimulated) and its centroid is determined to be within a predetermined maximum distance from focal point 54, then the feature is a target to be irradiated with laser light. The maximum area and maximum distance are preferably chosen to assure that the feature lies substantially within an area centered at focal point 54 whose size is substantially equal to the size of spot 70. Once a target is determined to be imaged on photosensitive surface 78, controller 24 controls laser 62 to radiate a pulse of light that is focused to spot 70 and deposits a desired amount of energy on the target.

Fig. 1B shows a schematic circuit 240 that illustrates how signals from photosurface 78 shown in insert 82 are used to determine whether or not to energize laser 62.

Let S84, S85, S91, S92, S93, and S94 represent signals received from detectors 84, 85, 91, 92, 93 and 94 respectively. Define a sum signal  $Z = (S91 + S92 + S93 + S94)$ . The magnitude of  $Z$  is a measure of the total amount of light received by photosensitive surface 78 from a feature imaged on photosensitive surface 78. Sum signal  $Z$  is used to determine whether or not a prospective feature for treatment is imaged on photosensitive surface 78 and to normalize signals from the individual detectors 91 - 94. In order to energize laser 62 the sum signal  $Z$  must be larger than a predetermined threshold, *i.e.* there must be a feature to be treated imaged on photosensitive surface 78 and the feature must be larger than a predetermined size as determined by the threshold.

Define  $S_X = |(S91 + S94) - (S92 + S93)|/Z$  and  $S_Y = |(S91 + S92) - (S93 + S94)|/Z$ . The magnitudes of  $S_X$  and  $S_Y$  indicate respectively how far off center the centroid of the imaged feature is from focal point 54 along two orthogonal "X" and "Y" directions. For a feature whose centroid is substantially located at focal point 54,  $S_X$  and  $S_Y$  are substantially equal to zero.

Circuit 240 comprises two comparators 242 and 244 for comparing  $S_X$  and  $S_Y$  to a voltage  $V_B$ . Signals  $S_X$  and  $S_Y$  are input to the plus inputs of comparators 242 and 244 respectively. Comparators 242 and 244 generate output signals only if  $S_X$  and  $S_Y$  respectively are greater than the bias voltage  $V_B$ .

5 The outputs of comparators 242 and 244 are input to a four way OR circuit 246. Signals S84 and S85 are also input to OR circuit 246. OR circuit 246 generates an output signal if either S84 or S85 is non-zero or if there is a signal from either comparator 242 or 244. The output of OR circuit 246 is input to AND circuit 248 after being inverted.

Sum signal Z is input to a comparator 250 that compares sum signal Z to a threshold  
10 voltage  $V_T$ . The output of comparator 250 is input to AND circuit 248. AND circuit 248 receives a signal from comparator 250 only if the sum signal Z is larger than  $V_T$ .

AND circuit 248 therefore generates a signal only if a feature of sufficient size is imaged on photosensitive surface 78, as indicated by sum signal Z, and only if there are no signals from detector 84 detector 85, comparator 242 and comparator 244. If there is an output  
15 signal from AND circuit 248 laser 62 is energized.

It is seen that  $V_B$  determines upper limits in the X and Y directions for the displacement of the centroid of a feature imaged on photosensitive surface 78. If  $S_X$  and  $S_Y$  are greater than  $V_B$ , the imaged feature is determined to be too far off center or too large to be an acceptable target for irradiation with laser light and AND circuit 248 will not generate an  
20 output signal.

It should be noted that circuit 240 assumes that a feature to be irradiated is brighter than background skin. A similar circuit (in which for example  $S_X$ ,  $S_Y$ , S84 and S85 are inverted) is used for processing images from photosensitive surface 78 if a feature to be irradiated is darker than the background skin.

25 Preferably, hand unit 22 comprises sensors (not shown) that detect whether or not window 28 is pressed to a patient's skin. Preferably, the sensors are pressure sensors that provide output signals responsive to pressure on window 28. Preferably, laser 62 is energized only if the output signals indicate that window 28 is being pressed to a patient's skin.

Preferably, circuitry that analyzes signals from photosensitive surface 78 to "acquire a  
30 target" and energize laser 62 performs these tasks in a time that is short compared to a "spot crossing time" *i.e.* the diameter of spot 70 divided by the scanning speed of focal point 54. As a result, signal analysis and target acquisition is performed, in accordance with a preferred embodiment of the present invention, continuously, substantially in real time.

Assume that microscope 32 oscillates with a frequency of 20 cps and that the amplitude of motion of focal point 54 is 2.5 cm. Focal point 54 therefore scans the skin with a velocity of 100 cm/s. If the size of spot 70 is 200 microns then the spot crossing time is  $2 \times 10^{-4}$  sec. Real time target acquisition and laser energizing is therefore easily accomplished, in accordance with a preferred embodiment of the present invention, using nanosecond circuitry and possibly even microsecond circuitry.

Whereas hand unit 22 comprises light source 72 for illuminating a patient's skin, in some preferred embodiments of the present invention light from laser 62 is used to illuminate the patient's skin. During scanning, laser 62 is not turned off but radiates light at low intensity, which is focused at focal point 54. The low intensity laser light is used to image the patient's skin. When a target is located, controller 24 controls laser 62 to increase the intensity of the laser light that it radiates and send a pulse of laser light that deposits a desired amount of energy on the target.

Fig. 2 schematically shows hand unit 22, which is shown Fig. 1A, in a cutaway view from a direction parallel to axis of rotation 44 shown in Fig. 1A. In Fig. 2, axis of rotation 44 is represented by a point 44 and beam splitting mirror 66 (Fig. 1A) occupies a shaded area labeled 66. Preferably, hand unit 22 comprises a handle 100. Skin 30 is schematically shown with a hair follicle 102. As a result of the pressure of window 28 on skin 30, skin 30 deforms slightly and molds itself to the shape of surface 29 of window 30. This assures that focal point 54 is properly positioned with respect to the surface of skin 30.

Oscillatory rotation of microscope 32 about axis of rotation 44 results in oscillatory motion of focal point 54 in the plane of Fig. 2 along an arc 104. Focal point 54 is shown in a number of different positions in Fig. 2. Short witness lines 106 and 108 indicate extreme positions of focal point 54 at the ends of arc 104. A witness line 110 marks the central position of the motion of focal point 54. Part of optic axis 38 is shown for the positions marked by the witness lines.

Microscope 32 is shown at a point of its motion about axis of rotation 44 at which focal point 54 is positioned at the location of hair follicle 102. At this position microscope 32 images hair follicle 102 on photosensitive surface 78 and controller 24 (Fig. 1A) determines that there is a target at focal point 54. Laser 62 (Fig. 1A) is controlled to radiate a pulse of light that is focused to spot 70 to coagulate follicle 102.

Whereas in hand unit 22 oscillatory motion of focal point 54 is achieved by rotating microscope 32, in some preferred embodiments of the present invention oscillatory motion of

focal point 54 is achieved by rotating mirror 66. In some preferred embodiments mirror 66 is rotated about axis of rotation 44. In some preferred embodiments of the present invention mirror 66 is rotated about an axis perpendicular to axis of rotation 44 and optic axis 38 that passes through their intersection. Fig. 3 schematically shows laser system 20 being used to  
5 depilate skin on an arm 120 of a patient, in accordance with a preferred embodiment of the present invention. The skin on arm 120 is preferably shaved to reveal hair follicles 122 (shown schematically with greatly exaggerated size) that are to be cauterized with laser light radiated from hand unit 22.

Hand unit 22 is held so that window 28 (shown in Figs. 1 and 2) is pressed to the  
10 surface of the skin of arm 120. With the surface of window 28 in contact with the patient's skin, hand unit 22 is moved back and forth along arm 120 in a direction indicated by double arrow line 124. Preferably, double arrow line 124 is substantially parallel to axis of rotation 44 of microscope 32, which is mounted inside hand unit 22 (Figs. 1 and 2). The oscillatory motion of microscope 32, causes focal point 54 (Figs. 1 and 2) of the microscope to move back and  
15 forth on the skin along a direction indicated by double arrow line 126. Double arrow line 126 is substantially perpendicular to double arrow line 124.

As a result of the motion of focal point 54 in the direction of line 126 in combination with the displacement of hand unit 22 along the direction of line 124, substantially all of a strip 128 of skin located between lines 130 is scanned for hair follicles 128. When these are located  
20 they are treated with laser light as described above. The width of strip 128 is substantially equal to the extent of motion of focal point 54 on the skin of arm 120. The length of strip 128 is equal to a distance that hand unit 22 is moved along the direction of double arrow line 30.

Fig. 4 schematically shows a hand unit 150 that is a variation of hand unit 22 shown in Figs 1- 3. Hand unit 150 is shown in a cutaway cross sectional view. Hand unit 150 preferably  
25 has a housing, which is not shown in Fig. 4 for clarity of presentation. In hand unit 22 all the optical elements of a microscope are comprised in a single rotating housing. Hand unit 150 on the other hand comprises a microscope 152 in which some of the optical components are mounted in a housing rotatable with respect to the hand unit housing and others are preferably fixed to the hand unit housing.

Components of microscope 152 are shown within dotted boundary curve 154.  
30 Microscope 152 has an ocular lens 156 mounted to the housing of hand unit 150 in a fixed position and an objective lens 158 comprised in an elbow shaped housing 160. Objective and ocular lenses 158 and 156 have optical axes 162 and 164 respectively. Objective lens 158



collects light from regions of a patient's skin 30 through a window 166 in the hand unit housing and has a focal point 168 located slightly below window 166.

Elbow housing 160 preferably has a circularly cylindrical tubular extension 170 having an axis of rotation 172. Axis of rotation 172 preferably intersects optic axes 162 and 164 at substantially 90°. Tubular extension 170 is mounted to a bearing 174 that is fastened to the hand unit housing. Bearing 174 enables tubular extension 170 to rotate about axis of rotation 172 but preferably prevents tubular extension 172 from moving parallel to axis 172. Tubular extension 170 is coupled to an appropriate motor or actuator (not shown) and rotated in an oscillatory motion about axis of rotation 172 similarly to the way in which tubular extension 42 of microscope 32 is rotated about axis of rotation 44. Focal point 168 therefore oscillates about axis of rotation 172 along an arc (not shown) in the same manner in which focal point 54 of hand unit 22 oscillates about axis of rotation 44 along arc 104 (Fig. 2).

Elbow housing 160 preferably comprises a mirror 176 that reflects light collected by objective 158 to a beam splitter 178. The light is represented by lines 180 having arrows thereon that indicate the direction in which the light travels. Beam splitter 178 reflects some of light 180 to ocular lens 156. Ocular lens 156 focuses and preferably directs light 180 towards a beam splitter 182 that transmits some of the light to a photosensitive surface 184 and reflects some of the light to a photosensitive surface 186.

Photosensitive surface 184, which is shown in plan view in insert 188, preferably comprises a quadrant detector 190 that is used to determine the position relative to focal point 168 of a prospective feature for laser treatment on the skin of a patient. Photosensitive surface 186, which is shown in insert 192, preferably comprises a detector 194 having a mask 196 located at the center of detector 194. Light incident on mask 196 does not reach detector 194. Detector 194 is preferably used to determine if the size of a prospective feature for laser treatment on a patient's skin is larger than a predetermined size. If a prospective feature is centered at focal point 168 its image will be centered on each of photosensitive surfaces 184 and 186. If the feature is larger than a predetermined maximum size, its image will be larger than mask 196 and detector 194 will generate signals responsive to the image indicating that the image is larger than the mask and therefore larger than the predetermined maximum size. In some preferred embodiments of the present invention quadrature detector 190 has a mask that covers all of quadrature detector 190 except for a region in the center preferably having the same area as mask 196. Masking quadrature detector 190 in this manner increases signal to noise from quadrature detector 190.

Signals generated by photodetectors in detectors 190 and 194 responsive to images of a prospective feature for laser treatment formed on photosensitive surfaces 184 and 186 respectively are transmitted to a controller (not shown). The controller analyzes the signals to determine if the feature is a target to be treated with laser light. In order for a feature to be a target, preferably the location of its centroid, as determined using signals from quadrature detector 190, must lie within a predetermined distance of focal point 168. In addition, preferably the size of the feature, as determined using signals from masked detector 194, must be less than the predetermined maximum size. Hand unit 150 comprises a laser 200 that is controlled by the controller. As in laser system 20 shown in Figs. 1 – 3, when a target is identified, the controller controls laser 200 to radiate a pulse of laser light to irradiate the target. Laser light radiated from laser 200 is piped by a light guide 202 to a collimating lens 204 that transmits the laser light to beam splitter 178. The laser light is represented by lines 206 having arrows thereon that indicate the direction of travel of the laser light. Some of laser light 206 is transmitted by beam splitter 178 to mirror 176, which reflects laser light 180 to objective lens 158. Objective lens 158 focuses the laser light to a spot 208. The predetermined maximum distance, maximum size and the size of spot 208 are preferably determined responsive to the size of a feature to be treated with laser light so that when a feature is determined to be a target, spot 208 will substantially cover all of the target.

In the description and claims of the present application, each of the verbs, “comprise” “include” and “has”, and conjugates thereof, are used to indicate that the object or objects of the verb are not necessarily a complete listing of components, elements or parts of the subject or subjects of the verb.

The present invention has been described using non-limiting detailed descriptions of preferred embodiments thereof that are provided by way of example and are not intended to limit the scope of the invention. Variations of embodiments described will occur to persons of the art. For example, in some preferred embodiments of the present invention the hand unit comprises a processor for processing data from photosensitive surfaces and determining whether a feature on the skin of a patient is a target. Whereas, oscillatory motion of the focal points of a microscope in a hand units has been described as resulting from rotational motion of the microscope the motion can be also be achieved by linear motion of the microscope. Furthermore, different configurations of photodetectors on photosensitive surfaces, other than those described, can also be used for locating and sizing prospective targets for laser treatment,

and these will occur to a man of the art. The scope of the invention is limited only by the following claims.

## CLAIMS

1. A laser system for treating features on the skin of a patient with laser light comprising:  
an imaging subsystem that locates features on the skin to be treated;  
5 a laser;  
laser optics that focuses light from the laser onto a feature located by the imaging subsystem; and  
a controller, that when a feature is located, controls the laser to radiate a pulse of laser light that  
is focused by the laser optics to a spot localized about the feature.  
10
2. A laser system according to claim 1 comprising a light source that illuminates regions  
imaged by the imaging optics with light for which the features to be treated have a reflectance  
different from that of clear skin so that a feature to be treated appears as a contrasted sub-region  
of an imaged region of the skin.  
15
3. A laser system according to claim 2 wherein the spectrum of the light radiated by the  
light source is tunable.
4. A laser system according to any of the preceding claims wherein the spot to which the  
20 laser is focused has an area substantially equal to an area characteristic of the size distribution  
of areas occupied on the skin by features to be treated, multiplied by a factor greater than one.
5. A laser system according to claim 4 wherein the factor is less than 2.
- 25 6. A laser system according to claim 4 wherein the factor is less than 1.5.
7. A laser system according to any of claims 4-6 wherein the factor is greater than about  
1.2.
- 30 8. A laser system according to any of the preceding claims wherein the controller controls  
the laser to radiate a pulse of light only if a located feature occupies an area on the skin  
consistent with the size distribution of areas occupied on the skin by features to be treated.

9. A laser system according to any of the preceding claims wherein the imaging subsystem scans an area of the skin and during scanning automatically locates features on the area to be treated.

5 10. A laser system according to any of the preceding claims wherein the imaging subsystem comprises:

at least one photosensitive surface that generates signals responsive to an image formed thereon; and

10 imaging optics that images light that it collects on the at least one photosensitive surface;

wherein, to scan the area, the imaging optics are moved relative to the skin so as to image regions in the scanned area onto the at least one photosensitive surface.

11. A laser system according to claim 10 wherein the imaging optics has a focal point and  
15 the spot to which the pulse of laser light is focused is centered at the imaging optics focal point.

12. A laser system according to claim 11 wherein the controller controls the laser to radiate a pulse of light only if a feature to be treated is determined to lie substantially within an area centered at the imaging optics focal point having a size substantially equal to the size of the  
20 spot to which the laser pulse is focused.

13. A laser system according to any of the preceding claims comprising circuitry that receives signals generated by the at least one photosurface responsive to an imaged region of the skin and processes the signals to locate contrasted sub-regions in the imaged region to  
25 locate features to be treated.

14. A laser system according to claim 13 wherein the at least one photosensitive surface comprises a single photosensitive surface.

30 15. A laser system according to claim 14 wherein the photosensitive surface comprises a quadrature detector.

16. A laser system according to claim 15 wherein signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is substantially centered within the spot to which the laser pulse is focused.

5 17. A laser system according to claim 15 or claim 16 wherein signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is larger than a predetermined minimum size consistent with the size distribution of areas occupied on the skin by features to be treated.

10 18. A laser system according to any of claims 15 - 17 wherein the photosensitive surface additionally comprises at least two photodetectors located adjacent to opposite sides of the quadrature detector.

15 19. A laser system according to claim 18 wherein if any of the photodetectors adjacent to sides of the quadrature detector generates a signal responsive to a contrasted sub-region imaged on the photosensitive surface, a portion of the sub-region is determined to lie outside the spot to which the laser pulse is focused and the laser is not energized.

20 20. A laser system according to claim 13 wherein the at least one photosurface comprises a first and a second photosensitive surface.

21. A laser system according to claim 20 wherein the first photosensitive surfaces comprises a quadrature detector.

25 22. A laser system according to claim 21 wherein signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is substantially centered within the spot to which the laser pulse is focused.

30 23. A laser system according to claim 21 or claim 22 wherein signals from the quadrature detector are used to determine whether a contrasted sub-region imaged on the quadrature detector is larger than a predetermined minimum size consistent with the size distribution of areas occupied on the skin by features to be treated.

24. A laser system according to any of claims 20 - 23 wherein the second detector comprises a photodetector having a mask that blocks light from impinging on an area located at its center.

5 25. A laser system according to claim 24 wherein if the photosensitive surface generates signals responsive to a contrasted sub-region imaged on the photosensitive surface, a portion of the sub-region is determined to lie outside of the spot to which the laser pulse is focused and the laser is not energized.

10 26. A laser system according to any of claims 10 - 21 wherein the imaging optics comprises an objective lens system having a focal point that collects light from regions imaged by the imaging subsystem and wherein the focal point of the imaging optics is the focal point of the objective lens system.

15 27. A laser system according to claim 26 wherein the imaging system comprises an ocular lens system that receives light collected by the objective lens system and images the received light on the at least one photosensitive surface.

20 28. A laser system according to claim 27 wherein the objective lens system is rotatable about an axis of rotation that intersects the optic axis of the objective lens system.

25 29. A laser system according to claim 28 wherein the laser optics comprises a collimating lens system that receives light radiated by the laser, which it collimates and transmits parallel to the axis of rotation.

30 30. A laser system according to claim 29 wherein the imaging optics comprises a reflector that reflects the collimated laser light towards the objective lens system along a direction parallel to the optic axis of the objective lens system so that the laser light is focused to a spot at the focal point of the objective lens system.

31. A laser system according to claim 30 wherein the reflector is a beam splitter.

32. A laser system according to claim 31 wherein the ocular lens system and the at least one photosensitive surface are positioned on a side of the reflector opposite to the side of the reflector on which the objective lens system is located.

5 33. A laser system according to claim 30 wherein the reflector is a mirror.

34. A laser system according to claim 33 wherein the ocular optics and the at least one photosensitive surface are stationary with respect to the axis of rotation.

10 35. A laser system according to claim 34 comprising a beam splitter positioned between the collimating lens and the mirror and wherein light collected by the objective optics is reflected by the mirror along the axis of rotation towards the beam splitter, which reflects some of the collected light incident on it towards the ocular lens system.

15 36. A laser system according to any of claims 28 - 35 comprising a motor or actuator that is coupled to the objective lens system and rotates the objective lens system with an oscillatory motion about the axis of rotation, so that the objective focal point moves back and forth along a planar arc having a fixed length.

20 37. A laser system according to any of claims 10 – 32 wherein the imaging optics and the at least one photosensitive surface are mounted within a hand held unit.

38. A laser system according to claim 37 wherein the light source is mounted in or on the hand held unit.

25

39. A laser system according to claim 37 or claim 38 wherein the laser is mounted within the hand held unit.

40. A laser system according to any of claims 37 – 39 wherein the controller is mounted in  
30 the hand held unit.

41. A laser system according to any of claims 37 – 40 comprising a power source mounted in the hand held unit.



42. A method for treating features on the skin of a patient with laser light comprising:  
optically scanning the patient's skin to locate features to be treated; and  
during scanning, when a feature is located, focusing a pulse of laser light energy to a  
5 spot that covers substantially completely the feature, which spot has an area substantially equal  
to an area characteristic of the size distribution of areas occupied on the skin by features to be  
treated, multiplied by a factor greater than one.
43. A method for depilating a patient's skin using laser light comprising:  
10 optically scanning the patient's skin to locate hair follicles in regions of the skin to be  
depilated; and  
during scanning, when a hair follicle is located, cauterizing the hair follicle by focusing  
a pulse of laser light energy to a spot that shadows substantially completely the hair follicle,  
which spot has an area substantially equal to an area characteristic of the size distribution of  
15 areas occupied on the skin by hair follicles, multiplied by a factor greater than one.
44. A method according to claim 42 or claim 43 wherein the factor is less than 2.
45. A method according to claim 42 or claim 43 wherein the factor is less than 1.5.  
20
46. A method according to any of claims 42-45 wherein the factor is greater than about 1.2.
47. A method according to any of claims 42 - 46 wherein scanning comprises moving an  
optical imaging system having a focal point over the patients skin to image different regions of  
25 the skin.
48. A method according to claim 47 wherein moving an optical imaging system comprises  
moving the focal point close to and along the patient's skin.
- 30 49. A method according to claim 47 or claim 48 wherein focusing a pulse of laser light  
energy comprises focusing the energy to a spot centered at the focal point.

50. A method according to claim 47 - 49 comprising analyzing imaged regions of the skin to locate features to be treated.

51. A method according to claim 50 wherein analyzing imaged regions comprises  
5 determining whether an imaged region of the skin has a feature having a size consistent with the size distribution of areas occupied on the skin by features to be treated.

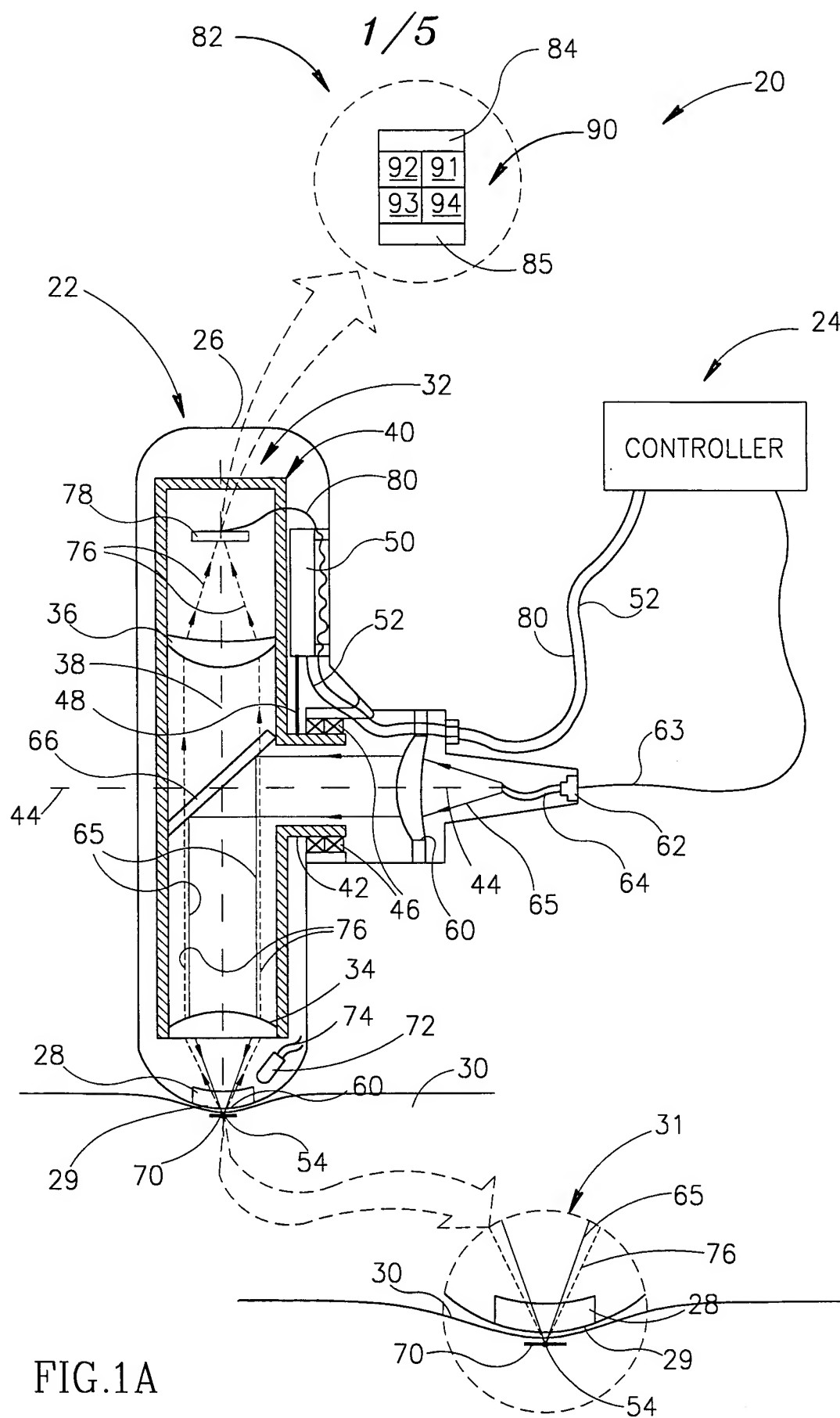
52. A method according to claim 50 or claim 51 wherein analyzing imaged regions  
10 comprises determining whether an imaged region of the skin has a feature to be treated located within a localized region on the skin which is centered at the focal point.

53. A method according to claim 48 wherein the localized region is substantially equal to the size of the spot to which the laser light is focused.

15 54. A method according to any of claims 48 - 53 wherein moving the focal point comprises moving the focal point with an oscillatory motion along a first direction on the skin.

55. A method according to claim 54 and comprising moving the focal point in a second  
20 direction substantially perpendicular to the first direction while the focal point is oscillating.

56. A method according to any of claims 47 - 55 wherein moving the optical imaging system comprises moving the optical imaging system by hand.



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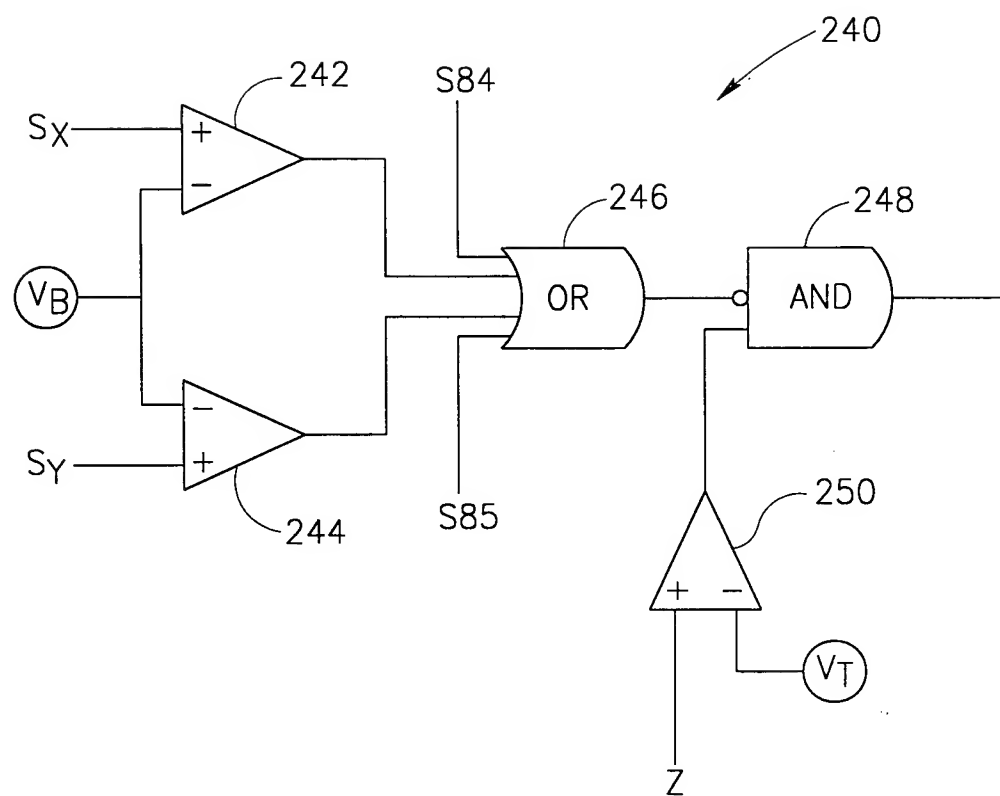


FIG.1B



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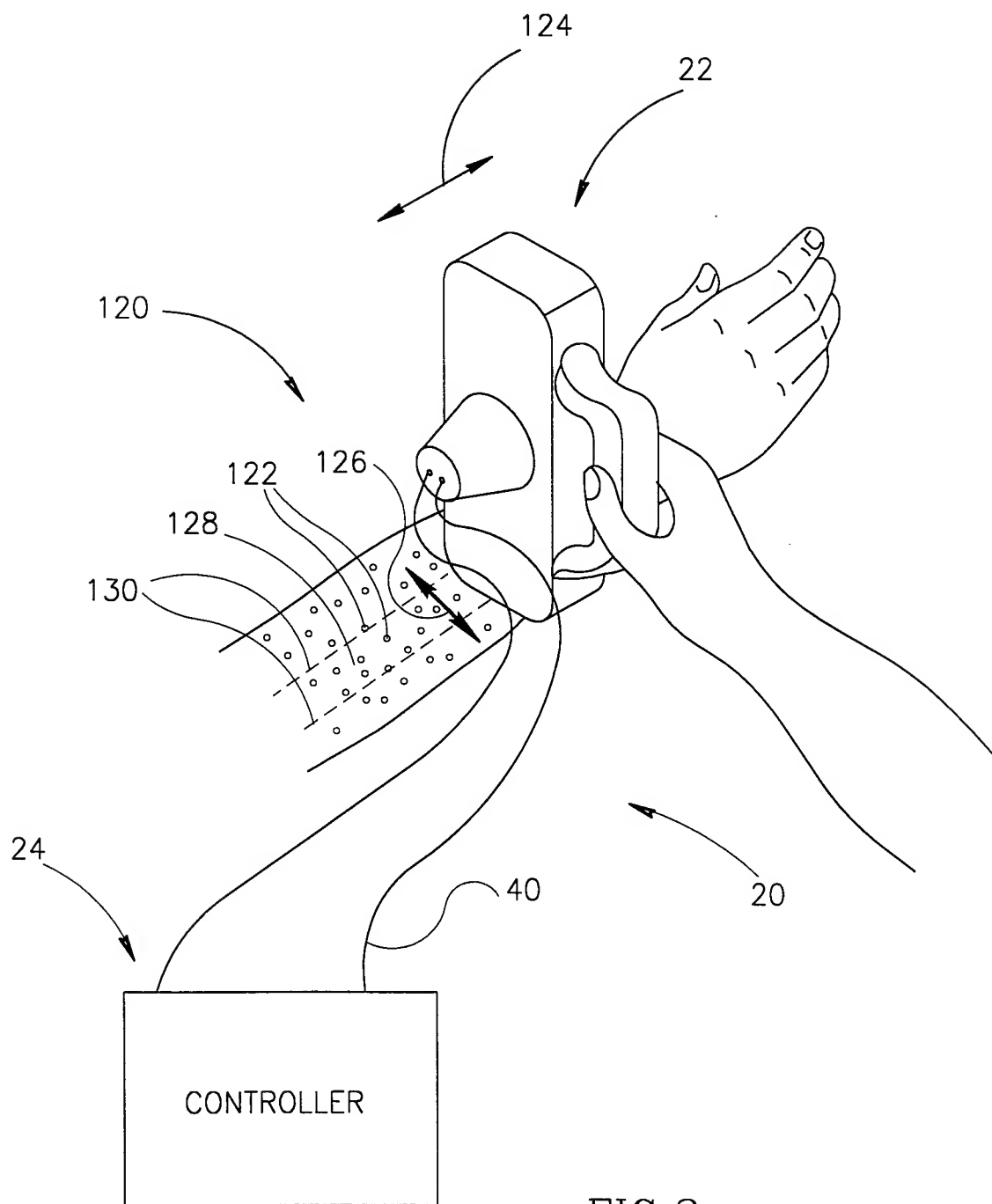
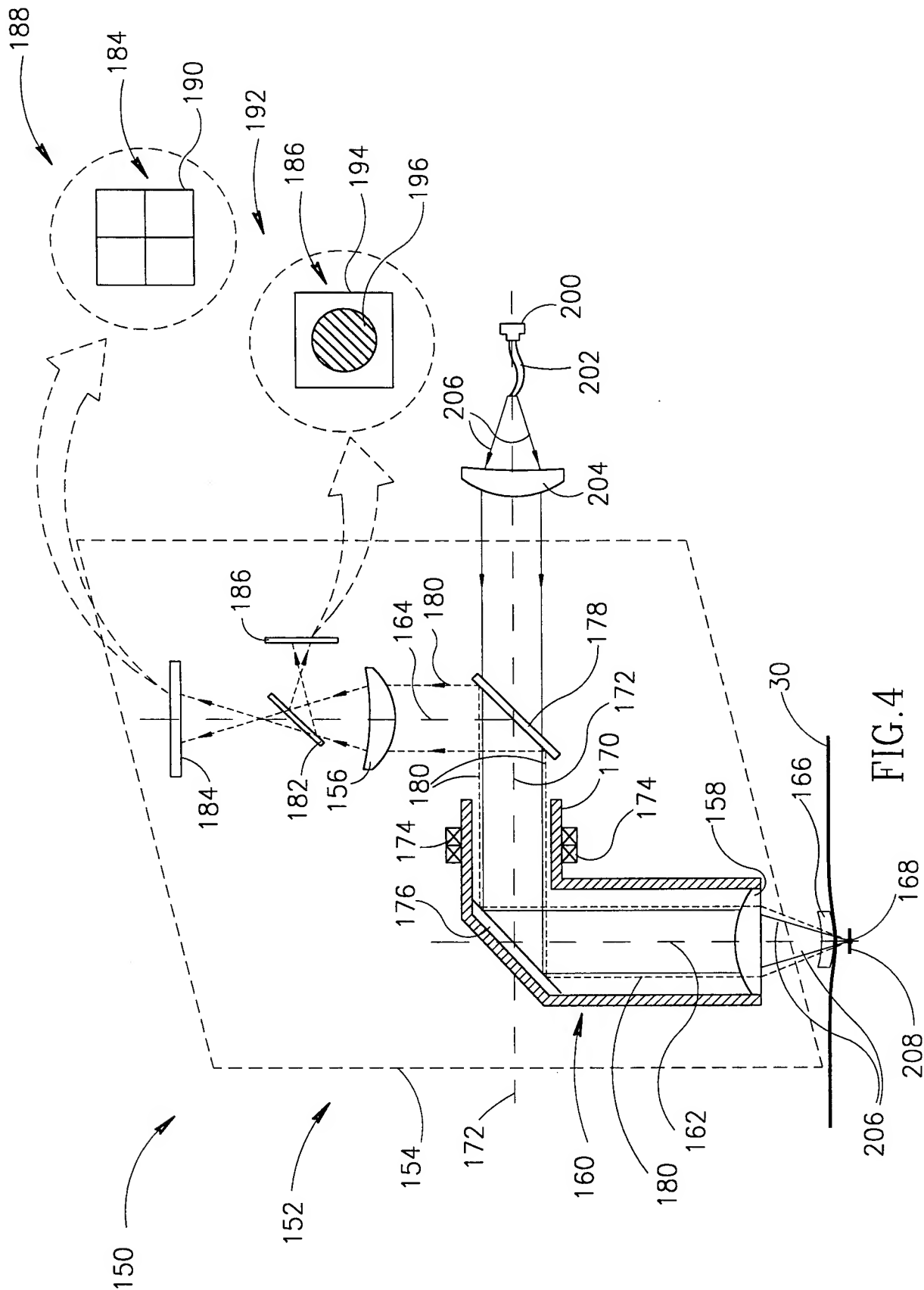


FIG.3



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/IL 99/00279

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61B18/20

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61B A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 11324 A (BALLE PETERSEN OLAV ;ASAH BJARNE (DK); ASAH MEDICO A S (DK); DOLLE) 11 March 1999 (1999-03-11) page 3, line 12 - line 22 page 6, line 9 - line 33 page 11, line 20 -page 12, line 21 page 14, line 8 - line 31 page 19, line 9 -page 20, line 20 ---	1-4,8,9, 13,14,43
X	DE 38 37 248 A (TEICHMANN HARRO DR MED ;TEICHMANN HEINRICH OTTO DR PHY (DE)) 3 May 1990 (1990-05-03) column 1, line 40 -column 4, line 38 ---	1,2,9,13
X	EP 0 880 941 A (NIDEK KK) 2 December 1998 (1998-12-02) column 15, line 43 -column 17, line 15; claim 11 --- -/--	1,2,9,13

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&amp;" document member of the same patent family

Date of the actual completion of the international search

19 January 2000

Date of mailing of the international search report

26/01/2000

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# INTERNATIONAL SEARCH REPORT

Inter. Appl. No.

PCT/IL 99/00279

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 531 740 A (BLACK MICHAEL) 2 July 1996 (1996-07-02) page 3, line 29 -page 5, line 18; figures 1,2 ---	1,2,9, 10,13
X	US 5 628 744 A (DAVENPORT SCOTT A ET AL) 13 May 1997 (1997-05-13) column 2, line 36 - line 50 -----	1,2,9,13

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL 99/00279

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 42  
because they relate to subject matter not required to be searched by this Authority, namely:  
Rule 39.1 (iv) PCT - Method for treatment of the human or animal body by therapy
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/IL 99/00279

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 9517130 A	29-06-1995

(19) World Intellectual Property Organization  
International Bureau



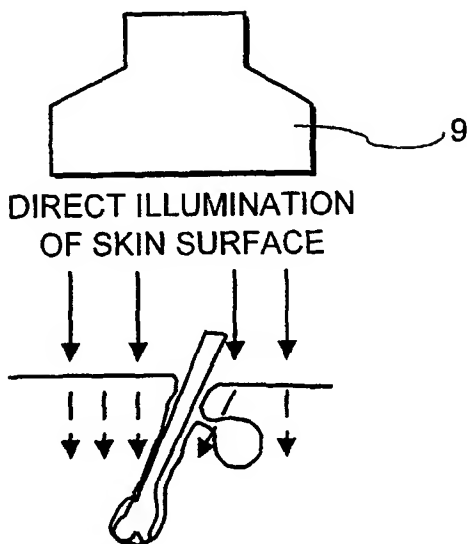
(43) International Publication Date  
14 December 2000 (14.12.2000)

PCT

(10) International Publication Number  
**WO 00/74781 A1**

- (51) International Patent Classification<sup>7</sup>: A61N 5/06, A61B 18/18
- (21) International Application Number: PCT/GB00/02170
- (22) International Filing Date: 5 June 2000 (05.06.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
9912998.3 4 June 1999 (04.06.1999) GB
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- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:**  
— With international search report.
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: COSMETIC DEPILATION KIT WITH PHOTSENSITIZER



(57) Abstract: A marker substance includes a photosensitive toxic material to tag subcutaneous hair growth cells of a target zone of skin. Illumination apparatus is used to illuminate the skin in the target zone with light of a wavelength selected to effect preferential interaction with the hair growth cells tagged with the marker substance, resulting in a toxic effect inhibiting the hair growth capability of the tagged illuminated cells; wherein. In the kit the marker substance may be provided in a form comprising discrete portions of the photosensitive toxic material and a carrier material, the portions to be mixed prior to application to the target zone. Additionally or alternatively, the illumination apparatus includes an applicator configured to deliver non-laser light and/or configured to be placed against the target zone skin to deliver the illumination to the tagged hair growth cells.

WO 00/74781 A1

## COSMETIC DEPILATION KIT WITH PHOTSENSITIZER

The present invention relates to a cosmetic depilation kit.

Laser hair removal is currently an effective and long term method for effecting cosmetic hair removal. An exemplary laser depilation technique is disclosed in EP-A-0732895. In such techniques, high intensity laser energy is directed towards the skin selectively heating hair surrounding the follicle leading to damage of the hair growth mechanism. If sufficient damage is induced, the hair follicle is effectively destroyed and the hair will not regrow. This technique has disadvantages, one such being that scarring and pigmentary changes can occur. This is particularly the case where the individual being treated has dark skin and/or light hair. Such techniques are also relatively slow, with the target zone needing to be covered by repeated laser pulses.

US-A-5669916 discloses a technique in which a hair is first plucked from a follicle before a photosensitive toxic material is directed along the path of the removed hair to the follicle. The toxic material is then activated by irradiation using laser.

An improved technique has now been devised.

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According to a first aspect, the present invention provides a cosmetic kit for use in inhibiting hair growth, the kit comprising:

- 5           a) a marker substance including a photosensitive toxic material to tag subcutaneous hair growth cells of a target zone of skin; and,
- 10           b) illumination apparatus for illuminating the skin in the target zone with light of a wavelength selected to effect preferential interaction with the hair growth cells tagged with the marker substance, resulting in a toxic effect inhibiting the hair growth capability of the
- 15           tagged illuminated cells; wherein:
  - (i) the marker substance is provided in a form comprising discrete portions of the photosensitive toxic material and a carrier
  - 20           material, the portions to be mixed prior to application to the target zone; and or,
  - (ii) the illumination apparatus includes an applicator configured to deliver non-laser
  - 25           light and/or configured to be placed against the target zone skin to deliver the illumination to the tagged hair growth cells.
- 30           The photosensitive toxic material is a material whose toxicity increases substantially upon exposure

-3-

illumination of predetermined wavelength at sufficient energy delivered. One such material is ALA (aminolevulinic acid); this and other materials are known in the art and described, for example in US-A-5669916.

5

The carrier material is beneficially a material easily absorbed into the skin and preferably comprises a moisturiser or absorbent emollient carrying the photosensitive toxic material in dissolved form or otherwise. It is important to maintain the carrier and the photosensitive toxic material separate until shortly prior to use in order to inhibit any adverse interaction between the materials prior to application to the skin of the target zone.

15

The portions of the photosensitive toxic material and the carrier material are dosed in a predetermined ratio. In one embodiment the proportion would be approximately 25% photosensitive toxic material to approximately 75% carrier material.

20

The kit beneficially includes a dispenser or a container-dispenser for dispensing the marker substance.

25

A container for the carrier material and or the photosensitive toxic material preferably affords light shielding of the photosensitive toxic material.

30

Mixing means is beneficially provided for mixing the photosensitive toxic material and the carrier material. The mixing means preferably permits mixing of the

-4-

photosensitive toxic material and the carrier material at a zone substantially sealed from the user.

Beneficially a container for the photosensitive toxic material and the carrier material comprises respective sealed zones containing the photosensitive toxic material and the carrier material respectively, the zones being configured to be selectively breached or ruptured permitting mixing of the materials. A mixing zone may be provided adjacent the breachable sealed zones, the mixing zone preferably communicating with a dispensing outlet.

The illumination apparatus preferably includes window means arranged to overlay the target zone skin, the illumination being directed via the window means.

In one embodiment, the illumination apparatus includes an illumination applicator having a flexible structure arranged to conform to the target zone skin body part.

20

The illumination apparatus preferably includes:

- a) an illumination applicator structure arranged to deliver illumination over a predetermined area;
- b) a waveguide to connect with the illumination applicator; and,
- c) a light source to direct light along the waveguide.

30



-5-

The illumination apparatus beneficially includes an illumination applicator structure having internal light reflecting walls and an associated light transmissive zone means through which reflected light is permitted to pass.

5 This may be achieved, for example, where the applicator structure comprises one or more lengths of fibreoptic (preferably the applicator structure comprises a plurality of lengths of fibre optic, the lengths being arranged to deliver light at different zones of the applicator

10 structure).

The marker substance is desirably preferentially absorbed by, or tagged to, hair growth cells in the target zone. The excess proportion of the applied marker substance not

15 absorbed by the hair growth cells is preferably metabolised and removed from the tissue by the normal action of the body. The technique according to the invention has been found to be effective even without the prior mechanical/physical depilation suggested in US-A-

20 5669916. Indeed such a step is discouraged due to the unnecessary trauma and pain it entails.

The hair growth cells targeted for tagging are preferably so called 'stem' cells in the 'bulge' area of the follicle

25 (adjacent the sebaceous gland). By effectively destroying or disabling the 'stem' cells once the hair has completed a growth cycle, a new hair cycle will be inhibited from starting, thereby preventing the follicle from functioning properly. The marker substance is therefore selected to

30 preferentially tag 'stem' cells.

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The marker substance is preferably topically applied to the skin at the target zone. The marker substance penetrates into the skin to preferentially tag the target cells (typically by being preferentially absorbed). The  
5 marker substance preferably comprises a photo therapy drug such as for example 5-Aminolaevolinic Acid (5-ALA). Desirably the drug is provided in a topically administrable form such as a cream or the like.

10 The interaction of the illuminating light with the marking substance preferably results in the desired hair growth inhibition. The interaction may be photochemical and/or photo-thermal in nature. For photochemical interaction, light of a predetermined wavelength induces a chemical  
15 reaction between the marker substance and the tagged cells resulting in destruction of, or disabling of, the tagged cells. For photo-thermal interaction, the incident light causes a temperature rise in the tagged cells to a degree sufficient to destroy or disable the tagged cell.

20 The wavelength of the illuminating light is preferably selected such that it is absorbed by the marker substance (or the tagged cell). The wavelength of the illuminating light is preferably substantially matched to the optical  
25 absorption characteristics of the marker substance.

The illuminating light is preferably substantially in the range 500nm-1000nm wavelength. The light is preferably concentrated within a relatively narrow bandwidth within  
30 the range. This may be achieved by filtering of the light or use of light emitting apparatus arranged to emit a

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discrete wavelength (or band of wavelengths). For example where 5-ALA is used as the marker substance to tag the cells it is preferred that the illuminating light includes on or more wavelengths substantially in the range 600nm-650nm.

The illuminating light may, for example, be laser (including semiconductor laser), white light (preferably filtered), or LED light.

The intensity of the light is determined by the quantity of light required to produce the necessary interaction with the tagged cells. Generally however the intensity required will be substantially lower than the intensity required for prior art laser depilation techniques. This enables the technique to be more suitable for unsupervised 'Home' use.

The light may be pulsed or applied as continuous wave. The light typically floods the target zone, which target zone is typically of an area in the range  $0.5\text{cm}^2$ - $10\text{cm}^2$ , more preferably  $1\text{cm}^2$ - $5\text{cm}^2$ . The energy applied per pulse to the target zone is preferably substantially in the range 40J or less (more preferably 25J or less).

The possibility of using lower intensity and non-laser light also enables a greater area target zone to be simultaneously illuminated, with reduced risk of skin burn. The technique is therefore safer and quicker.

The invention will now be further described, in a specific embodiment, by way of example only and with reference to the accompanying drawings in which:

5        Figure 1 is a schematic representation of a mammalian hair  
follicle;

Figure 2 is a schematic representation, similar to Figure 1, showing a first stage in application of the depilation technique;

Figure 3 is a schematic representation similar to Figures 1 and 2, showing a subsequent stage in the technique;

15       Figures 4 and 5 are schematic plan and side views  
respectively of a container-dispenser for the marker  
substance according to the invention;

Figures 6 and 7 show alternative general embodiments of  
20 illumination apparatus for inclusion in a kit according to  
the invention;

Figure 8 is a schematic view of a laser diode illumination apparatus for inclusion in a kit according to the invention;

Figure 9 is a schematic view of LED illumination apparatus for inclusion in a kit according to the invention;

30 Figure 10 is a schematic view of 'white light' illumination apparatus for inclusion in a kit according to

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the invention;

Figure 11 is a schematic view of alternative 'white light' illumination apparatus for inclusion in a kit according to the invention;

Figure 12 is a schematic view of a pad or patch applicator structure illumination apparatus for inclusion in a kit according to the invention;

Figure 13 is a perspective view of the applicator pad or patch of figure 12;

Figure 14 is a sectional view of the fibreoptic used in the pad or patch of figures 12 and 13; and

Figure 15 is a schematic longitudinal section of the fibreoptic of figure 14.

Referring to the drawings and initially to Figure 1, there is shown human hair follicle supporting a hair shaft 1 growing through the epidermis 2 and dermis 3 of mammalian skin tissue. 'Stem' cells 7 are present in the 'bulge' region 4 adjacent the sebaceous gland 5. Stem cells have a relatively high turnover/life cycle and are responsible for instituting cyclical growth of the hair from the follicle.

In accordance with the invention, a drug formulation including 5-Aminolaevolinic Acid (5-ALA) is provided in a form for topical administration to the outer surface of

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the skin 6. The drug 5-ALA is selected because it is selectively absorbed and retained in stem cells 7 when penetrating into the epidermal layer 3 (via epidermis 2) thereby effectively tagging the stem cells.

5 Concentrations of the drug not absorbed in the stem cells 7 are metabolised and removed from the tissue by the normal action of the body.

After a predetermining period of time to allow the excess

10 "marker" drug to be removed from the target zone tissue (other than from the "tag" stem cells 7), the target zone of the skin is directly illuminated from externally of the body by means of an illumination device 9 which supplies light of a preselected wavelength matched to a preselected

15 characteristic absorption wavelength of the marker drug (now tagging stem cells 7).

The intensity of the light supplied, and duration of supply of the light, is controlled such that either

20 photochemical or photo-thermal interaction (or both) of the light with the tagged stem cells 7 causes disabling or destruction of the relevant stem cell 7 without disabling or destroying, substantially, the surrounding tissue material. This results in the tagged and disabled stem

25 cell being inhibited from acting further to produce hair from the relevant follicle.

The technique, by selectively marking/tagging and destroying stem cells preferentially (and the associated

30 matching of the wavelength of the illuminating light) enables relatively low intensity light to be used, which

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may flood the target zone of the skin enabling a relatively large area of hair covered skin to be treated simultaneously. Typically, the light from the illumination device 9 is pulsed to enable thermal relaxation of the skin to occur between consecutive pulses. Typically, the energy supplied to the skin surface by the illuminating device 9 does not exceed 25J, before significant thermal relaxation of the skin is permitted.

10

The illuminating device may comprise laser, semiconductor laser, white light illumination device (typically with a filter) or an LED device. The wavelength band width emitted where 5-ALA is used as the marker is preferably substantially within the range 600nm - 650nm (which may be achieved by filtering if required).

15

The low intensity nature of the light required to effect depilation using the technique according to the invention, enables the technique to be relatively safe when compared to prior art laser hair removal techniques. The drug formulation and illumination device may therefore be sold as a consumer kit for "home" use.

20

Referring to figures 4 to 15 a "home use" kit for cosmetic depilation would typically comprise a power supply and lighting apparatus 10, 11 (see figures 6 and 7) for direct connection to mains power supply. The apparatus 10, 11 either includes flexible electric connection to a light source 12 for application of illuminating radiation to the skin or, a "fixed" light source 13 and fibreoptic

25

30

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connection 14 to an applicator 16.

5 The other essential element of the kit is the market substance typically provided in a container 20 (see figures 4 and 5) which comprises a heat sealed plastics container/dispenser 20 having sealed chambers 21, 22, 23.

10 Chamber 21 contains the ALA material and chamber 23 carries the moisturiser/emollient carrier cream. A manual pinch pressure causes seals 24, 25 to be ruptured and the respective materials to be urged from chambers 21, 23 into mixing chamber 22 where they become thoroughly, and intimately, mixed. A cap 26 is subsequently broken from the end of nozzle 27 permitting the ALA and carrier  
15 mixture to be squeezed out of the container dispenser 20 under manual pressure.

The container dispenser 20 ensures that the correct proportions of ALA drug and carrier are mixed, and that  
20 mixing may be delayed until the point of application.

Following application of the mixture topically to the target zone of skin, and subsequently waiting the required length of time to permit the concentration of ALA in the  
25 non-target tissue to be reduced to the required low level, the illumination apparatus is applied to the skin and switched on.

Various forms of illuminating apparatus may be used. The  
30 apparatus 110 in figure 8 includes a laser diode light source 125 contained within a protective casing 126 and



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including focussing optics 127 arranged to ensure the light is directed through a protective window 128. Typically the window 128 is held against the skin of the target zone to ensure correct delivery of the illuminating light to the target zone.

In the embodiment shown in figure 9 a 2D array of LEDs (light emitting diodes) 225 is utilised. Focussing optics 227 ensure the light is directed through the protective window 228 in a similar manner to the arrangement of figure 8.

In the apparatus shown in figure 10, an electric filament "white light" source is used. The source 325 is surrounded by a protective housing 326 including a shaped reflective surface 327 arranged to direct the light out of the housing via protective window 328.

In the embodiment shown in figure 11, a white light filament source 325 is once again used. In this embodiment an internally reflecting light guide (such as a fibreoptic) is used. The fibreoptic may be connected to a light applicator to be connected to the skin as will be described hereafter.

The apparatus of figure 12 shows an applicator pad or patch structure 426 which is typically flexible in nature, permitting the pad 426 to be conformed to the shape of the body part to which it is applied. As shown in figures 13 to 15 additionally, light is directed to the pad or patch structure 426 by a flexible fibreoptic 435 which has a

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connector 436 arranged for mating connection to a corresponding connector 437 provided for the pad or patch structure. The pad or patch structure 426 has an imbedded fibreoptic arrangement 440 including a series of spaced lengths of fibreoptic 441 extending across the pad or patch structure. In the embodiment shown in figure 13, the fibreoptic path lengths form a serpentine arrangement, although a number of paths connected in parallel would also provide a convenient and workable arrangement. As shown in figure 14 the fibreoptic 440 includes a reflective surface cladding 442 surrounding a core 443. The surface cladding 442 ensures total internal reflection about the circumference of the fibreoptic except for an unclad window length 445 through which light can be emitted.

The pad or patch structure as shown in figures 12 to 15 provides a convenient arrangement in that light can be distributed widely over a large area of skin surface in a convenient and safe manner.

Particular benefits of the invention are the arrangement of the carrier and the photosensitive toxic material in discrete separate package portions, easily mixable at the required time in order to ensure that detrimental effects of early mixing or incorrect dosage ratios are avoided. The illumination apparatus configured to deliver non-laser light and/or configured to be placed against the target zone skin provide additional safety benefits and ensure that the skin is radiated to a consistent degree during treatment. This makes the kit particularly suitable for

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consumer/home use.

## Claims:

1. A cosmetic kit for use in inhibiting hair growth, the  
5 kit comprising:
- a) a marker substance including a photosensitive  
toxic material to tag subcutaneous hair growth  
cells of a target zone of skin; and,
- 10 b) illumination apparatus for illuminating the skin  
in the target zone with light of a wavelength  
selected to effect preferential interaction with  
the hair growth cells tagged with the marker  
15 substance, resulting in a toxic effect  
inhibiting the hair growth capability of the  
tagged illuminated cells; wherein:
- (i) the marker substance is provided in a form  
20 comprising discrete portions of the  
photosensitive toxic material and a carrier  
material, the portions to be mixed prior to  
application to the target zone; and or,
- 25 (ii) the illumination apparatus includes an  
applicator configured to deliver non-laser  
light and/or configured to be placed  
against the target zone skin to deliver the  
illumination to the tagged hair growth  
30 cells.

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2. A cosmetic kit according to claim 1, wherein the portions of the photosensitive toxic material and the carrier material are dosed in a predetermined ratio.
- 5 3. A cosmetic kit according to claim 1 or claim 2, including a dispenser for dispensing the marker substance.
- 10 4. A cosmetic kit according to any preceding claim, including a container for the carrier material and or the photosensitive toxic material.
- 15 5. A cosmetic kit according to claim 4, wherein the container affords shielding of the photosensitive toxic material.
- 20 6. A cosmetic kit according to any preceding claim, wherein mixing means is provided for mixing the photosensitive toxic material and the carrier material.
- 25 7. A cosmetic kit according to claim 6, wherein the mixing means permits mixing of the photosensitive toxic material and the carrier material at a zone substantially sealed from the user.
- 30 8. A cosmetic kit according to any preceding claim, wherein a container for the photosensitive toxic material and the carrier material comprises respective sealed zones containing the photosensitive toxic material and the carrier material respectively,

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the zones being configured to be selectively breached or ruptured permitting mixing of the materials.

- 5           9.    A cosmetic kit according to claim 8, wherein a mixing zone is provided adjacent the breachable sealed zones, the mixing zone communicating with a dispensing outlet.
- 10          10.   A cosmetic kit according to any preceding claim, wherein the illumination apparatus includes window means surface arranged to overlay the target zone skin, the illumination being directed via the window means.
- 15          11.   A cosmetic kit according to any preceding claim, wherein the illumination apparatus includes an illumination applicator having a flexible structure arranged to conform to the target zone skin body part.
- 20          12.   A cosmetic kit according to any preceding claim, wherein the apparatus includes:
- 25           (a)   an illumination applicator structure arranged to deliver illumination over a large area;
- (b)   a waveguide to connect with the illumination applicator; and,
- 30           (c)   a light source to direct light along the waveguide.

13. A cosmetic kit according to any preceding claim,  
wherein the apparatus includes an illumination  
applicator structure having internal light reflecting  
5 walls and an associated light transmissive zone means  
through which reflected light is permitted to pass.
14. A cosmetic kit according to claim 13, wherein the  
applicator structure comprises one or more lengths of  
10 fibreoptic.
15. A cosmetic kit according to claim 13 or claim 14,  
wherein the applicator structure comprises a  
plurality of lengths of fibre optic, the lengths  
15 being arranged to deliver light at different zones of  
the applicator.

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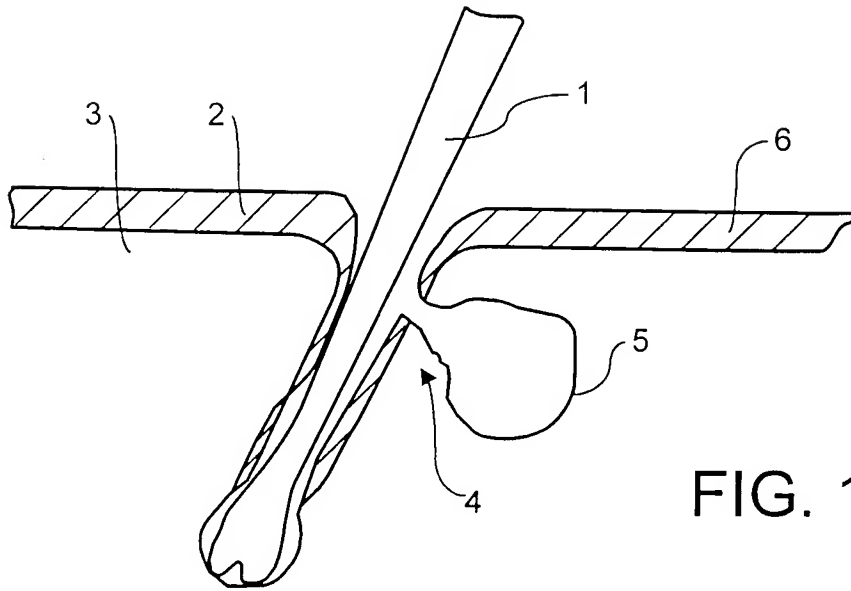


FIG. 1

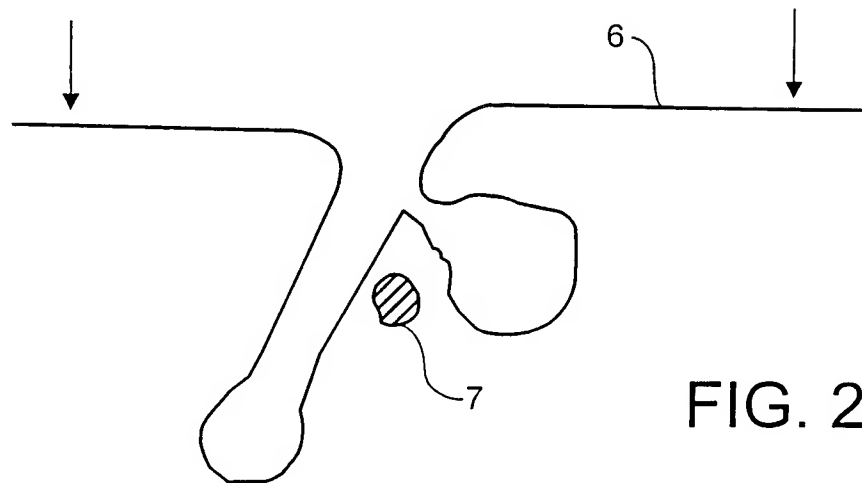


FIG. 2

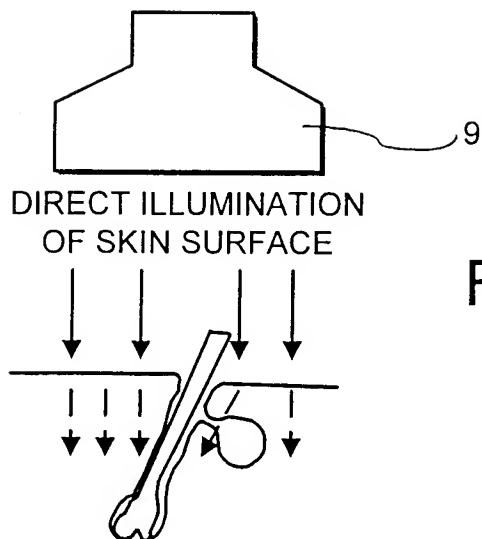


FIG. 3



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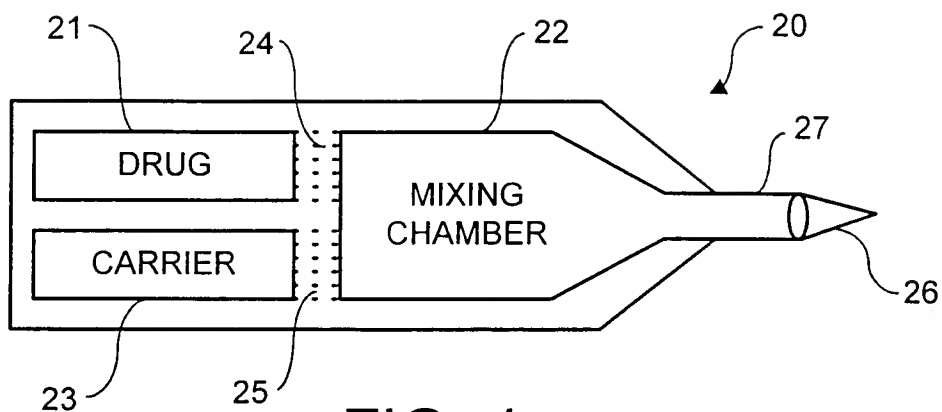


FIG. 4

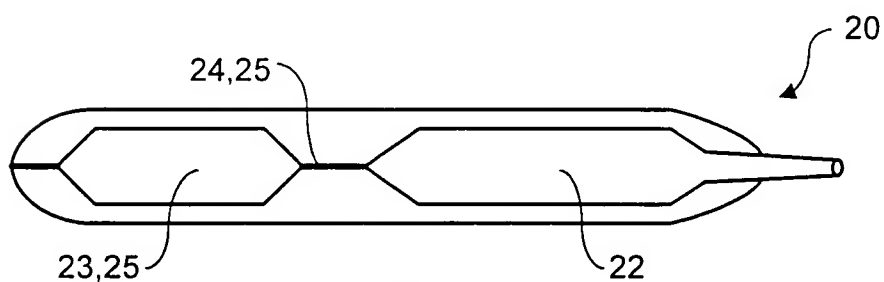


FIG. 5

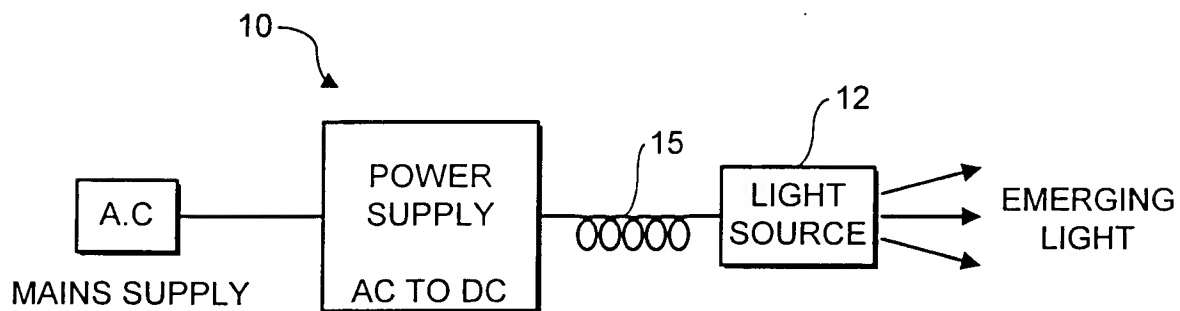


FIG. 6

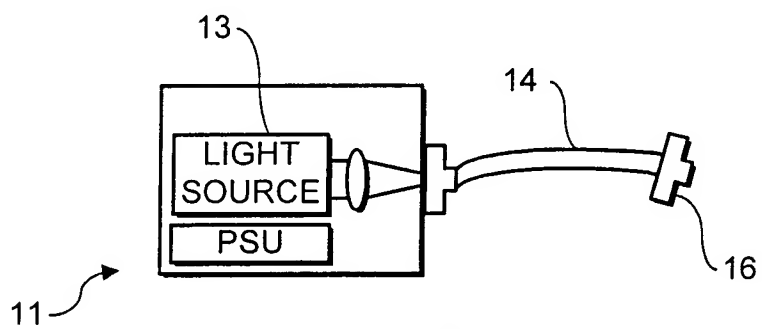
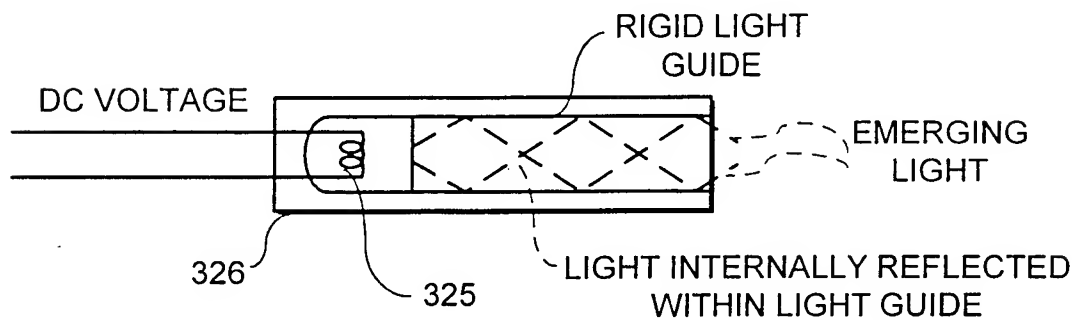
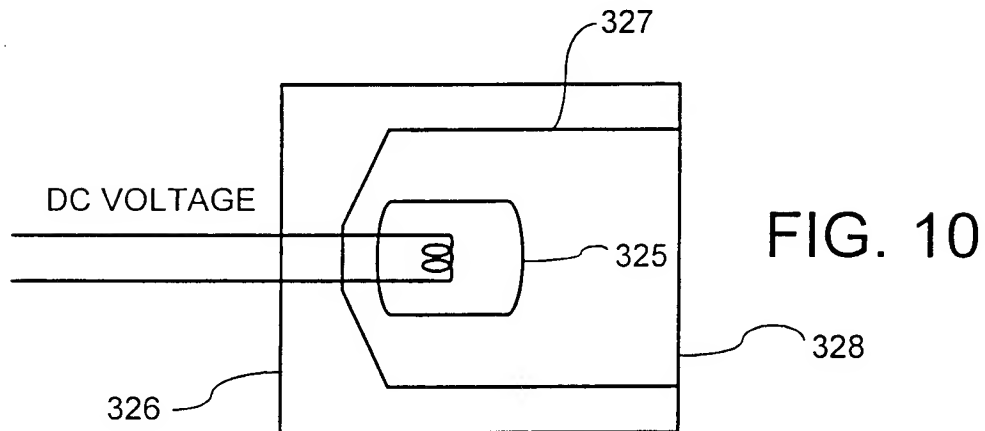
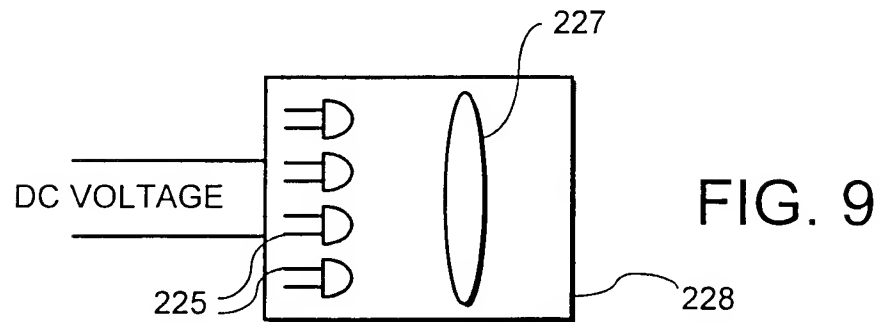
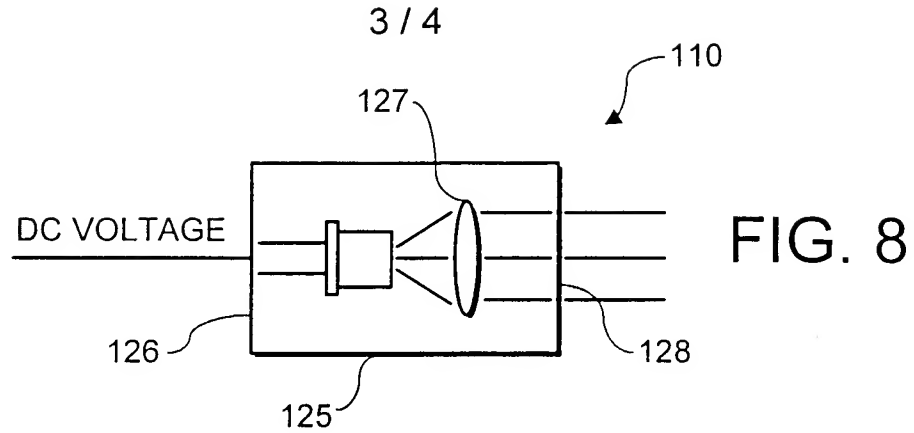
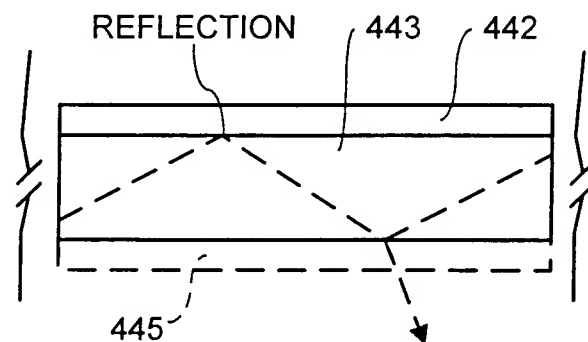
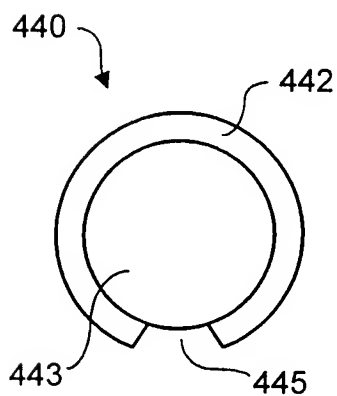
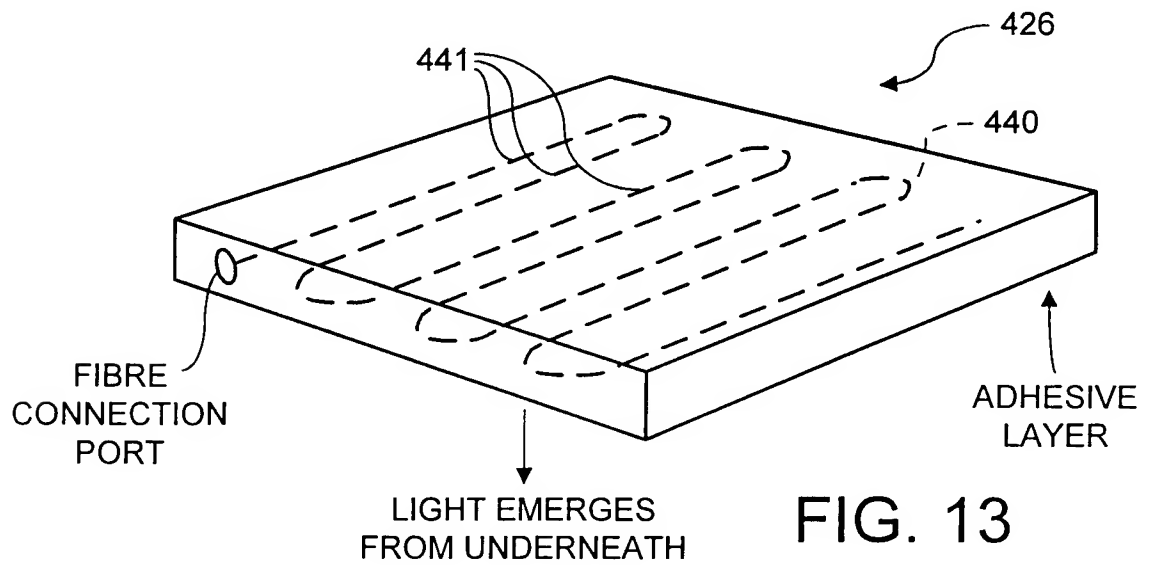
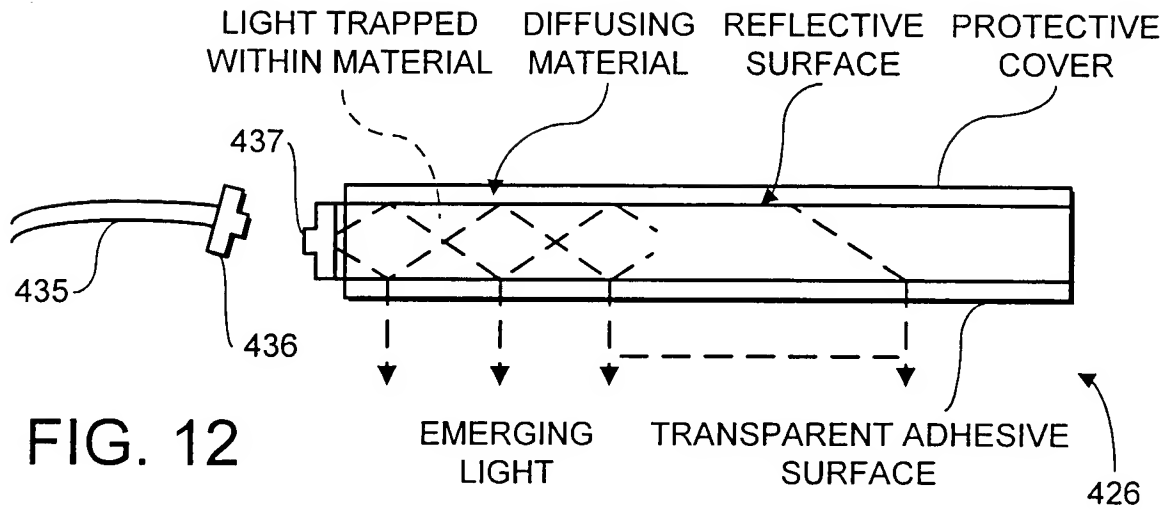


FIG. 7



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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/02170

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7 A61N5/06 A61B18/18

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61N A61B A61K A61M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	----	8, 9, 11, 13-15
X	WO 95 07077 A (NORWEGIAN RADIUM HOSPITAL RESE ;DZIEGLEWSKA HANNA EVA (GB); GIERSK) 16 March 1995 (1995-03-16) page 3, paragraph 1 page 5, paragraph 1 -page 6, paragraph 1 page 8, paragraph 2 -page 10, paragraph 3 ----- -/--	1-7, 10, 12



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&amp;" document member of the same patent family

Date of the actual completion of the international search

19 September 2000

Date of mailing of the international search report

26/09/2000

Name and mailing address of the ISA

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/02170

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
28 December 2000 (28.12.2000)

PCT

(10) International Publication Number  
**WO 00/78242 A1**

(51) International Patent Classification<sup>7</sup>: **A61B 18/20**

(21) International Application Number: PCT/US00/16576

(22) International Filing Date: 15 June 2000 (15.06.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
60/140,003 18 June 1999 (18.06.1999) US  
60/165,814 16 November 1999 (16.11.1999) US

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(74) Agents: **FLOAM, D., Andrew et al.**; Needle & Rosenberg, P.C., Suite 1200, The Candler Building, 127 Peachtree Street, N.E., Atlanta, GA 30303-1811 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

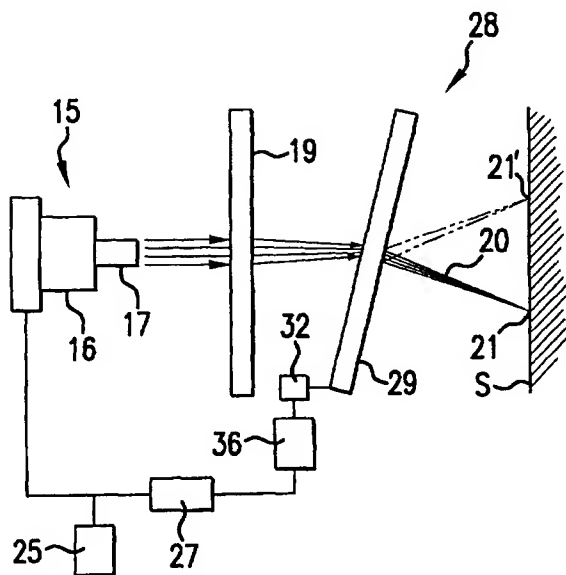
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— With international search report.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: LIGHT BEAM GENERATION AND FOCUSING DEVICE



(57) Abstract: An improved light beam generation and focusing device (15, 50) is disclosed. The device has a light source (16, 51) constructed and arranged to emit at least one beam of light (20), and a lens assembly (17, 19, 56) constructed and arranged to focus the at least one beam of light on a surface plane. The device is constructed and arranged to sequentially direct the at least one beam of light to at least two spaced locations (21, 21') on the surface plane. The lens assembly comprises a collimating lens (17), and a spaced focusing lens (19). The collimating lens may comprise a micro-lens, and more preferably a cylindrical micro-lens mounted on the light source. In a first embodiment, the device is provided with a beam steering device (28) having a beam steering optical element (29), and a drive assembly (31) for actuating the beam steering optical element such that the at least one beam of light is directed to the at least two spaced locations on the surface plane. In a second embodiment, the device is provided with a plurality of light sources mounted to a mounting block (52), each light source emitting a separate beam of light to separate focal points, respectively, on the surface plane.

WO 00/78242 A1

## LIGHT BEAM GENERATION AND FOCUSING DEVICE

### CROSS REFERENCE TO RELATED APPLICATIONS

The patent application claims priority to, and the benefit of the filing date  
5 of, U.S. Patent Application Nos. 60/140,003 and 60/165,814, filed June 18,  
1999, and November 16, 1999, respectively.

### FIELD OF THE INVENTION

The invention relates in general to light beam generation and focusing  
10 devices, such as laser porators. More particularly, the invention relates to an  
improved light beam generation and focusing device adapted to emit at least  
one focused beam of light directed to at least two spaced locations on a  
surface plane.

### BACKGROUND OF THE INVENTION

The use of laser porators for forming micropores in the stratum corneum  
has proven to be an important advancement in the healthcare field. Laser  
thermal ablation devices, such as that described in U.S. Patent No. 5,885,211,  
provide a means of quickly and efficiently forming a micropore in the stratum  
20 corneum so that interstitial fluids can be easily gathered therefrom for testing  
the analytes present in the fluid. This has proven to be a very simple yet  
effective way of testing for glucose, for example. Moreover, the use of laser  
porators of the type described in the above-referenced patent has led to the  
development of improved glucose monitoring and testing systems, such as  
25 those developed by SpectRx, Inc. of Norcross, Georgia.

When used as a porator for forming micropores in the stratum corneum  
of a person's skin, the known types of laser ablation devices emit and focus a  
beam of light at a focal point on the stratum corneum for defining, *i.e.* burning,  
an opening in the skin layer without penetrating any deeper into the epidermis  
30 of the person being tested. Thereafter, interstitial fluids will flow into the  
opening, or can be drawn into the opening by the use of a separate device, for  
example, the electro-poration device described in U.S. Patent No. 6,022,316.



Additional laser ablation devices are described in U.S. Patent No. 5,643,252, and in U.S. Patent No. 6,027,496.

What is common to the laser porators of the aforementioned patents, and as illustrated in Fig. 1 hereof, is a laser poration device 5 provided with a light source 6, typically a laser of some type, which laser emits a beam of light directed toward a collimating lens 9. The collimating lens gathers the beam of light and forms it into a columnar beam of light, and directs the beam of light to a spaced focusing lens 11. From the focusing lens, the beam of light is directed toward and focused on a focal point 13 defined on a spaced surface plane.

U.S. Patent No. 5,643,252 illustrates a laser ablation device of the known type in Figs. 1 and 3 thereof, and also shows in Fig. 5A thereof an ablation device having a spaced arrangement of prisms positioned with respect to the light source for use in splitting the beam of light emitted from the light source into separate beams of light, each beam of light being simultaneously directed to a surface plane. The device of the '252 patent also discloses, in Fig. 5B, a powered acousto-optic modulator for use in creating separate beams of light.

A problem with the known types of laser ablation/poration devices, however, results from the size of the device necessary to emit and focus a beam of light, and the need or desire to form more than one micropore in the stratum corneum of a person being tested.

There is a need, therefore, for a portable laser poration device which can quickly and easily emit at least one focused beam of light directed to at least two spaced focal points on a surface plane spaced from the device. Moreover, there is a need for such an improved device which remains relatively compact, yet flexible enough for use in a variety of applications. There is also a need for an improved laser porator which will more efficiently gather the beam of light emitted from the light source, focus the beam of light, and direct it to the at least two spaced locations on the surface plane.

### SUMMARY OF THE INVENTION

The present invention provides an improved light beam generation and focusing device adapted for use in emitting and directing at least one focused beam of light to at least two spaced locations on a surface plane, which may include the stratum corneum of a person, and which overcome some of the design deficiencies of the known art. The light beam generation and focusing device of this invention provides a simple and efficient device which allows for a greater degree of flexibility in use when compared to the known types of laser porators. Moreover, the relative simplicity of the device of this invention, when contrasted with the known laser porators, addresses the problems of efficiently and cost effectively focusing at least one beam of light on a surface plane for defining an opening therein, and more preferably for defining an opening in at least two spaced locations therein.

The invention attains this degree of flexibility, as well as simplicity in design and construction, by providing an improved light beam generation and focusing device having a light source constructed and arranged to emit at least one beam of light, a lens assembly constructed and arranged to focus the at least one beam of light on the surface plane, and which is also constructed and arranged to direct the at least one beam of light to at least two spaced locations on the surface plane.

The lens assembly of the device comprises a collimating lens positioned with respect to the at least one beam of light, and a focusing lens spaced therefrom. The collimating lens may comprise a micro-lens, and more particularly may comprise a cylindrical micro-lens mounted directly to the light source. The light source may comprise a laser diode, and may further comprise a single active element laser diode chip, or multiple active element laser diode chips.

The device may also include, in one embodiment, a beam steering device constructed and arranged to direct the at least one beam of light to the at least two spaced locations on the surface plane. The beam steering device

includes a beam steering optical element, and a drive motor, or drive motors, for moving the optical element so as to direct the at least one beam of light from a first location on the surface plane to a spaced second location thereon. The drive motor(s) may comprise a stepper motor, or other motors designed to  
5 function similarly.

The beam steering optical element may comprise a wedge prism or a tilted or angled plane in a first embodiment, each of which is driven by the drive motor. The optical element may also comprise a holographic or a diffractive optical imaging element in a second embodiment thereof such that a motor is  
10 not required, the optical element serving both to split the optical energy, *i.e.* the at least one beam of light, and to direct the at least one beam of light to the at least two spaced locations on the surface plane.

In another embodiment of the invention, the light beam generation and focusing device will be sized and shaped to fit within the hand of the device  
15 user, and will comprise a power supply, a light source, and a beam steering device fitted within the housing for directing the at least one beam of light emitted therefrom to the at least two spaced locations on the surface plane, or alternately may comprise at least two separate light sources within the housing, *i.e.*, two separate laser diodes, used to emit separate beams of light.

Accordingly, in still another embodiment of the invention, the light source  
20 will comprise at least two laser diodes mounted on a common mounting block. Each of the laser diodes will preferably comprise a laser diode chip, although other types of suitable light emitting sources may be used. Each laser diode chip will be spaced approximately eight hundred (800) microns apart from each  
25 adjacent one of the laser diode chips for forming a predetermined pattern of light beams directed toward the surface plane.

The device also includes a controller/microprocessor coupled to the light source and/or to the beam steering device, where one is provided, for controlling the emission of the at least one beam of light, and for directing the

at least one beam of light to the at least two spaced locations on the surface plane.

An improved method of emitting a focused beam of light directed to a surface plane results from the unique construction of this invention, the method including the steps of emitting at least one beam of light from a light source, passing the at least one beam of light through a lens assembly for being focused on the surface plane, and sequentially directing the at least one beam of light to at least two spaced locations on the surface plane with the device.

The step of sequentially directing the at least one beam of light may include the step using a beam steering device, or using at least two spaced light sources. Moreover, the method may include the step of sequentially directing the at least one beam of light to at least four spaced locations on the surface plane for forming a predetermined pattern thereon.

The objects, features, and advantages of the present invention will become apparent upon reading the specification, when taken in conjunction with the accompanying drawings, to which the invention is directed.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a schematic illustration of a known type of laser poration device.

Fig. 2 is a schematic illustration of a first embodiment of the light beam generation and focusing device of this invention.

Figs. 3A and 3B are schematic illustrations of a second embodiment of the light beam generation and focusing device of this invention.

Fig. 4 is a schematic illustration of the light beam generation and focusing device of Figs. 3A and 3B.

Fig. 5 is a schematic illustration of a combined light source and lens assembly for use with the light beam generation and focusing device of this invention.

Figs. 6A-6C illustrates three separate embodiments of a beam steering optical element that may be used as a part of the beam steering device of the invention.

Fig. 7 is a partial schematic perspective illustration of a third  
5 embodiment of the light beam generation and focusing device of this invention.

Fig. 8 is a partial exploded schematic view of the embodiment of the light beam generation and focusing device of Fig. 7.

Fig. 9 is a schematic illustration of the light beam generation and focusing device of Figs. 7 and 8.

10 Fig. 10 is a schematic side elevational view along line 10-10 of Fig. 7.

Fig. 11 is a schematic illustration of a fourth embodiment of the light beam generation and focusing device of this invention.

Fig. 12 is a schematic illustration of a fifth embodiment of the light beam generation and focusing device of this invention.

15 Fig. 13 is a circuit diagram of the control circuit used in connection with the embodiments of the light beam generation and focusing device of Figs. 2-12.

### **DETAILED DESCRIPTION OF THE INVENTION**

20 Referring now in detail to the drawings, in which like reference characters indicate like parts throughout the several views, a first embodiment of the light beam generation and focusing device of 15 of this invention is illustrated in Figs. 2 and 5. The device 15 is provided with a light source 16, here a suitable laser diode, for example those laser diodes manufactured by  
25 High Power Devices, or other laser diodes, also referred to as semiconductor diode lasers.

The light source 16 will preferably be a low-cost solid state laser diode capable of delivering a beam a light having an emission wave length of approximately eight hundred nanometers, or at such other wave lengths and  
30 power levels necessary for the intended purposes, which may include, but are

not limited to, the forming of a micropore in the stratum corneum of a person's skin. Also, it is anticipated that the laser diode will be sized such that it will be sufficiently small so as to be portable enough to fit within a hand-held housing.

Although not shown in Figs. 2 and 5, the light source 16 will be powered by a  
5 suitable power source 25, which may include batteries, including, but not limited to, lithium, lithium-ion, nickel-metal hydride, and nickel-cadmium batteries; a capacitatively charged power source, for example a storage capacitor; or a regulated wall type power supply capable of converting an electrical line voltage into the voltage needed to operate the device.

10 As shown in Figs. 2-5, the light source 16 is fitted with a collimating lens 17 mounted directly to the light source. It is envisioned that the collimating lens 17 will comprise a micro lens, and may also therefore include a cylindrical micro-lens adapted to gather the light emitted from the light source 16, and to collimate the light so that it is emitted therefrom as an aligned and oriented  
15 beam of light directed toward a spaced focusing lens 19. The focusing lens will direct the beam of light toward a focal point 21 defined on a spaced surface plane "S", which is any desired surface plane, to include the stratum corneum of a person, or any other surface on which the beam of light is to be focused.

Fig. 5 illustrates an alternate embodiment of the arrangement of the  
20 device 15 shown in Fig. 2, in that the focusing lens 19 is affixed to a casing 23, the casing in turn being affixed to the light source 16 along with the collimating lens 17 so that the light source and lens assembly are formed as one compact assembly designated by the reference character "L." The construction shown in Fig. 5 offers a compact and efficient arrangement which is advantageous for  
25 use in a hand-held light beam generation and focusing device.

A second embodiment of the light beam generation and focusing device  
15 is illustrated in Figs. 3A & B, and in Fig. 4. In this embodiment of the device the light source 16 is again provided with a collimating lens 17, a micro-lens, fitted directly to the light source, with a spaced focusing lens 19 for focusing  
30 the beam of light 20. However, and unlike the first embodiment of this

invention, the device 15 includes a beam steering device 28 constructed and arranged to receive the focused beam of light, and to direct the beam of light to at least two spaced locations on the surface plane. This is accomplished by positioning a beam steering optical element 29 between the focusing lens 19  
5 and the surface plane S, such that the beam steering optical element intercepts the focused beam of light, and selectively directs the beam of light to a first focal point 21 on the surface plane, and then to at least a second spaced focal point 21' on the surface plane, shown in broken lines.

The beam steering device will include in a first embodiment thereof a  
10 drive assembly 31, best shown in Figs. 3A and 3B, comprised of a drive motor 32, here a stepper motor, a mounting collar 33 for mounting the stepper motor to the casing 23 of the light source 16, a gear train 35 having a drive gear 35' rotated by the stepper motor 32, a driven gear 35" affixed to the beam steering optical element 29, and a motor controller 36 for operating the stepper motor  
15 so that it will move the beam of light 20 from the first focal point 21 to at least the second spaced focal point 21', as shown in Fig. 4. Although not shown, it is envisioned that more than one drive motor may be provided as a part of the beam steering device.

Referring now to Figs. 3A and 3B, the light beam generation and  
20 focusing device 15 includes a hand-held housing 24 in which the device is fitted. The housing is sized and shaped to fit within the hand of the device user, and is provided with a suitable power supply 25, as described above. It is preferred, although not required, that the power supply be battery powered, and more preferably, that it be one of the known types of rechargeable  
25 batteries.

As shown in Figs. 3A and 3B, the device 15 will include the compact collimating lens assembly shown in Fig. 5, which assembly will have the beam steering device 28 fitted thereto by the mounting collar 33 as described above. A controller 27, also referred to herein interchangeably as a microprocessor or  
30 microcontroller, is provided as a part of the device, and is positioned within the

housing 24 for controlling the light source such that a pulsed laser beam is generated and emitted therefrom, and which also signals a motor controller 36 for controlling the operation of the beam steering device drive motor.

5 The construction of the controller 27 and of the motor controller 36 is not shown in greater detail as these are otherwise conventional control or microprocessor chips adapted for use in both controlling the operation of the light source 16, as well as operating the motor 32. Each of the controller 27 and the motor controller 36, as well as the controller 64 described hereinbelow, therefore comprises a conventional microprocessor available from a variety of  
10 vendors/manufacturers in known constructions, and which will either be pre-programmed or programmable, as known, and will also be provided with a memory or access to a memory storage and retrieval device.

Moreover, although a stepper motor 32 is disclosed herein for use in driving the beam steering optical element 29, it is understood by those skilled  
15 in the art that any suitable motor, or controllable actuator, including, but not limited to a servomotor, a solenoid, a pneumatic cylinder, a hydraulic cylinder, or the like, could be used for this purpose, as desired. A stepper motor is preferred here for its ability to precisely control the movement of the beam steering device.

20 The actual physical construction of the device 15 shown in Figs. 3A and 3B is not discussed in greater detail for the reason that the manner and method of assembling the components is well known, and will comprise the use of a PC board to which the controllers 27 and/or 36 will be affixed, and to which the power supply 25 will also be connected through the known types of  
25 electronic circuits, as is the light source 16.

Although, the device 15 shown in Figs. 3A and 3B uses the compact light source and lens assembly L shown in Fig. 5, it is also envisioned that the device could use conventional spaced collimating and focusing lenses which are not affixed to or mounted on the light source 16 and the casing 23,



respectively, as shown, for example, in U.S. Patent No. 5,885,211 to *Eppstein et al.*, the provisions of which are incorporated fully herein by this reference.

Moreover, although the beam steering optical element 29 shown in Fig. 4, as well as in Fig. 6A is an inclined optical plane 38, it is anticipated that other  
5   embodiments of the beam steering optical element may be used, as shown in Figs. 6B and 6C. Referring now to Fig. 6B, the beam steering optical element 29 may comprise a wedge shaped prism 39 positioned anywhere in the optical beam path, but which is preferably positioned between the focusing lens (not shown) and the focal point 21 on the surface plane (Fig. 4). The prism 39 will  
10   be moved by the drive motor 32, the prism being held by a suitable support structure or framework with respect to the light source 16 of Figs. 2-5. Both the optical plane and the prism will be rotated about a central axis "A" positioned coaxially with the axis of the light source for directing the beam of light to the at least two spaced locations 21, 21', on the surface plane.

15       The optical plane 38 comprises a tilting, flat optical window, or plate, which may be positioned between either the light source and the collimating lens, or between the focusing lens and the surface plane. The focal point of the beam of light can thereby be steered by tilting this flat optical window in the x and y dimensional planes, where the thickness of the window affects the  
20   beam of light via refraction of the light beam leading to a lateral translation of the focal point in an amount related to the degree of tilt in the desired direction.

The steering of the beam of light in this fashion offers some cost advantages over an optical wedge in that an optical window/plane is a simpler element to fabricate.

25       Each of the optical plane 38 of Figs. 4 and 6A, and the prism 39 of Fig. 6B comprise an optical quality glass or plastic element, respectively, the plane 38 being a plate or sheet of glass or plastic, whereas the prism 39 will shaped as a prism of any suitable construction or configuration. All that is required is that the plane 38, prism 39 be suitable for bending light to be incident at the  
30   required distance from the optical axis, and be provided with suitable

transmissability and anti-reflective coatings at the desired wavelengths. The optical plane of Figs. 4 and 6A is mounted in an inclined fashion in a holder, while the prism is mounted in an erect manner.

Yet another embodiment of the beam steering device 28 is shown in Fig. 6C, which embodiment does not utilize the drive assembly 31 of Figs. 3A and 3B. Instead, a holographic or diffractive optical element 40 is used which masks the beam of light received from the upstream light source, such that discrete beams of light 20 are passed toward the surface plane to the separate focal points 21, 21" thereon. This type of holographic or diffractive imaging into multiple focal points is preferably done using a monochromatic light source, such as a laser diode. Additionally, when using these types of holographic or diffractive optical elements, to ensure an equal distribution of optical energy to the various focal points, it is preferable to mask the first order image and use only the multiple second order images emitted from the element.

Although, reference has been made hereinabove to a first focal point 21 and a second focal point 21', or 21", respectively, it is envisioned that the beam steering embodiments of the device 15 will be used to direct the beam of light to at least two, and as many more spaced locations/focal points on the surface plane as desired. A preferred light pattern here is shown as having four spaced focal points on the surface plane spaced at least eight hundred microns apart from one another for defining a predetermined pattern of focal points, or openings if the device is being used to define a plurality of micropores through the stratum corneum and into the viable layers of the epidermis of a person. The beams of light emitted from the device, in each of its several embodiments, will preferably penetrate to a depth of at least 80 to 100 microns beneath the outermost surface of the skin layers. This type of construction is desirable for allowing the interstitial fluids to be collected from a plurality of closely grouped micropores for expediently testing the interstitial fluids for analytes or for any other desired purpose(s).

It is envisioned, therefore, that the beam(s) of light can be formed into any type of geographic pattern capable of being defined on a surface plane, which may thus include a hexagonal shaped pattern, a rectangular pattern, a circular pattern, or a pattern of any desired type, based upon the operating  
5 program stored within the controller 27 and/or the motor controller 36 of the device, all as desired by the end user of the device, based on the known types of programmable control/microprocessor chips available in the art, and the known methods of programming same.

A fourth embodiment of the light beam generation and focusing device  
10 50 is illustrated in Figs. 7-9. Referring first to Figs. 7 and 8, in this embodiment of the invention, rather than using a beam steering device 28 as shown in Figs. 3A - 4, a plurality of light sources 51, again laser diodes as described above, are mounted to a common mounting block 52 in the desired geometric pattern to be defined on the surface plane of Figs. 10-12. Each one of the light  
15 sources 51 will be mounted on the mounting block, which also functions as either a ground or an electrode, by an insulated wire bonding pad 54 for forming either the anodic or cathodic lead for the laser diode, respectively, whereas the respective cathodic/anodic leads will be formed through the known wire bonding techniques. The emitting facets of the respective laser  
20 diodes will preferably be aligned along the "z" dimensional axis such that when collimated and re-imaged to focus on the surface plane, the focal point of each individual laser diode will lie on the common surface plane.

Each of the insulated wire bonding pads 54 will be separately positioned within a respective one of the depressions 54' defined within the mounting  
25 block, with the laser diodes being soldered or otherwise bonded to the heatsink and wired to the bonding pads, and thus to the mounting block 52. The wire bonding pads are insulated from the mounting block so that the block can provide the "opposite" electrical supply, be it positive, or negative, as desired. The mounting block, be it a common ground or a common positive, will

preferably comprise a block of high thermal conductivity copper, or other high quality thermally conductive heatsink materials.

Four spaced light sources 51, illustrated in Fig. 7 as four separate laser diodes, together define a predetermined pattern shown by the broken lines as  
5 designated by the reference character "D". Each of the respective laser diodes will be spaced approximately eight hundred microns apart from each adjacent laser diode within this predetermined pattern. Here, rather than emitting a single beam of light with a single light source and then "steering" the beam of light, a plurality of separate light beams, in this instance four light beams, will  
10 be emitted from the device in sequential fashion toward the surface plane S. This eliminates, entirely, the need for any kind of mechanical device interposed between the respective light sources 51 and the surface plane. As with the beam steering embodiment of the invention, the beams of light emitted from the respective light sources are capable of being formed into any type of  
15 geographic pattern capable of being defined on a surface plane, as governed by the mounting pattern of the laser diodes on the mounting block.

Referring now to Fig. 9, the construction of the light beam generation and focusing device 50 is described in greater detail. The device 50 is provided with four light sources 51, each of which comprises a laser diode, for  
20 example a single active element laser diode chip. Each laser diode is affixed to the mounting block 52 as an assembly 51A. The assembly fits within a lens holder 55, to which a lens assembly 56 is fitted. The lens assembly 56, as shown in Fig. 9, includes a collimating lens 58 and a spaced focusing lens 59. A casing 60 is fit over the lens assembly 56, and hold the lens assembly in  
25 position with respect to the lens holder 55 and the laser diode assembly 51A.

The casing 60, lens assembly 56, and laser diode assembly 51A are fitted within a housing 62, the housing being sized and shaped to be held within the hand of a user. A suitable power supply 63 is provided within the housing, this being the same type of power supply as is power supply 25,  
30 described above.

The device 50 will include a controller/microcontroller 64, a known type of microprocessor, as described hereinabove, and is provided with a resistor pin network 66 which provides a series of pull down resistors used to prevent the lasers from firing without the proper actuating command. The device 50  
5 also includes a three pin header 67, provided as a programming port for the controller 64, in known fashion. The controller 64, as well as the resistor network 66, and the header 67 are fit within an electronics compartment defined within the housing, with an electronics compartment cover 68 fitted thereto for enclosing the electronics controls of the device within the housing.  
10 Still referring to Fig. 9, a plurality of spaced pogo pins 70 are provided for connection to the power supply 63, assuming the power supply comprises batteries, as described hereinabove, batteries being preferred for providing ease of portability in the use of the device. The housing is also provided with a power switch 71 for operating the device, and includes a plurality of  
15 conventional fasteners 72 for affixing the laser diode assembly 51A to the housing, and a plurality of fasteners 74 for affixing the electronics compartment cover to the housing as well. The device 50 is also provided with a bi-color LED 75 for the purpose of indicating a ready status in which the device is charged and ready for use, and a firing status indicating that the light source,  
20 the laser diode or diodes, are firing. For example, a flashing green light may be used to indicate the ready status, and a flashing red or amber light to indicate that the device is firing, and to meet the appropriate BRH/FDA laser safety warning requirements.

Referring now to Fig. 10, the embodiment of the device shown in Figs. 7-9 is shown in a schematic side elevational view. Two spaced light sources  
25 51, a pair of laser diodes, are shown affixed to the mounting block 52. Each light source emits a separate beam of light 20 toward a first collimating lens 58, which gathers and collimates the light, and passes it to a spaced downstream focusing lens 59, such that the beams of light are separately focused at focal  
30 points 21, 21' on the surface plane. Again, although only two focal points are

shown, it is understood by reference to Figs. 7 and 8, that there will be at least four such focal points formed into the shape of a predetermined pattern on the surface plane.

The device of Fig. 10 may be used with any conventional lens assembly, such as that shown in Fig. 9, and comprising lens assembly 56. However, the embodiment of light beam generation and focusing device 50 shown in Figs. 7-10 may also be used with the micro-lens construction of the device shown in Figs. 2-5, such that, and as shown in Fig. 11, a micro-lens 77 is affixed to each light source/laser diode 51 for gathering and collimating the respective light beams, and passing the light beams to a spaced focusing lens 59, which then passes the light beams to two separate focal points 21, 21'.

If full advantage of the construction shown in Figs. 2-5 is to be achieved, then the construction of Fig. 12 results, in which each one of the light sources 51 is provided with a compact lens assembly and casing as shown in Fig. 5, such that the micro-lens is affixed directly to the laser diode, and a casing is also affixed to the laser diode, whereupon the focusing lens is affixed to the casing so that no separate collimating and focusing lens assemblies are needed for focusing and directing the separate beams of light 20 towards the focal points 20, 21' on the surface plane.

In the embodiment of the light beam generation and focusing device shown in Figs. 2-6, the construction of the device, namely there being a beam steering device 28 provided as a part thereof, results in the sequential direction of a focused beam of light to at least two, and more preferably four, spaced focal points 21 on the surface plane. In particular, for the embodiments of the device shown in Figs. 6A and 6B, a stepper motor and a focal plane 38 and/or a prism 39 are used to steer the beam of light. As it necessary to physically move the beam steering optical element 29 for directing the beam of light 20 to any separate one of the different focal points 21, 21', and so on defined on the surface plane, the direction of the beam of light must necessarily be done in

sequence with a first focal point being established, and with any and all subsequent focal points being established in sequential order.

For the embodiment of the device 15 shown in Fig. 6C, using the holographic or diffractive optical element 40, and which does not otherwise use a drive motor as a part of the beam steering device, it is possible that the beam of light may be simultaneously directed to the several focal points formed on the surface plane. If, however, and not illustrated but envisioned, the holographic/diffractive element is used in combination with a beam steering device positioned between the light source 16 and the downstream holographic plate, then the focal points would be established sequentially, all as desired, and as programmed into the controller 27 of the device.

With regard to the embodiment of the device illustrated in Figs. 7-12, however, still greater flexibility results from the construction of the device in that the controller 64 will preferably operate each of the four light sources/laser diodes 51 sequentially for emitting separate beams of light from each respective laser diode toward the surface plane. However, due to the construction of the device shown in Figs. 7-12, it is also possible that the controller 64 could be programmed so that each one of the light sources 51 fires simultaneously, although this is not preferred when compared to sequential operation of the device in that the peak power drain on the battery of the device would be much greater than from sequential operation. Also it is possible that if all of the laser diodes of the device were operated simultaneously the device would heat up more quickly, requiring a greater cooling capacity for the mounting block 52, and there would likely be a noticeable discomfort factor for the person on whose stratum corneum, for example, the multiple light beams were focused as the surface plane.

Referring to Fig. 13, a control circuit 100 is shown which may be used to operate either the stepper motor for the beam steering device 28 (Figs. 3A-4, 6A-6B) or to drive the multiple lasers in the embodiment shown in Figs. 7-12. The control circuit 100 comprises a programmable controller 110, the power

switch 71 (referred to above), and a plurality of laser drive circuits 120. In addition, the circuit 100 drives status indicators 130 and 132 (referred to above) which are, for example, the bi-colored light emitting diodes (LEDs) 75. Each laser drive circuit 120 comprises a field effect transistor (FET) 122 that  
5 act as a high current switch to activate a corresponding one of the light sources 51. The light sources 51 are, for example, laser diodes. A diode 124 is included in each laser drive circuit 120 to provide protection for the light sources 51 in the event a static discharge occurs. The parallel resistor-capacitor combination in each laser drive circuit 120 acts as a filter for pulse  
10 smoothing and to reduce electrical switching spikes that may occur when the control circuit 100 is powered on.

The controller 110 is, for example, a programmable micro-controller and is programmed to time the on/off time signals coupled to the laser drive circuits 120 for sequencing the operation of the light sources 51. For example, four of  
15 the pins may be programmed to the proper sequence of time on vs. time off to drive the drive (stepper) motor for the beam steering device 28. Alternatively, four of the pins may be programmed to the proper sequence of time on vs. time off to power the field effect transistors which act as the high current switches used to turn the light source(s), here laser diodes, on and off in the desired  
20 sequence. The outputs of the controller 110 that is coupled to the laser drive circuits 120 are found at pins 11-14 thereof.

The signal on each of these pins is coupled to the gate of a FET 122 of a corresponding laser drive circuit 120, and causes the desired time on vs. time off for a light source. The controller 110 also drives the status indicators 130  
25 and 132 according to the status of the signals on pins 11-14. Programming of the controller 110 is achieved by a suitable programming interface 112 that supplies programming signals to pins 3 and 4 of the controller 110.

The controller 110 is also programmable to generate similar timing signals at pins 11-14 to drive a stepper motor in the beam steering device 28  
30 shown in Figs. 3A-4, 6A-6B, thereby controlling the location of the laser beam.



Although, several embodiments of the invention have been disclosed in the foregoing specification, it is understood by those skilled in the art that many modifications and other embodiments of the invention will come to mind to which the invention pertains, having the benefit of the teaching presented in the foregoing description and associated drawings. It is thus understood that the invention is not limited to the specific embodiments disclosed herein, and that many modifications and other embodiments of the invention are intended to be included within the scope of the appended claims. Moreover, although specific terms are employed herein, as well as in the claims, they are used in the generic and descriptive sense only, and not for the purposes of limiting the described invention, nor the claims which follow.

## WE CLAIM:

1. A light beam generation and focusing device for directing at least one focused beam of light at a surface plane, said device comprising:
  - a light source constructed and arranged to emit at least one beam of light; and
  - a lens assembly constructed and arranged to focus said at least one beam of light on the surface plane;said device being constructed and arranged to sequentially direct the at least one beam of light to at least two spaced locations on the surface plane.
2. The device of claim 1, said lens assembly comprising a collimating lens positioned with respect to the at least one beam of light and a focusing lens spaced from the collimating lens.
3. The device of claim 2, said collimating lens and said focusing lens each comprising a fresnel lens.
4. The device of claim 2, said collimating lens comprising a micro lens.
5. The device of claim 4, said micro lens comprising a cylindrical micro lens.
6. The device of claim 4, said micro lens being mounted to said light source.

7. The device of claim 1, said light source comprising at least one laser diode.
8. The device of claim 7, said at least one laser diode further comprising a semiconductor laser diode chip.
9. The device of claim 7, said lens assembly having a micro lens affixed to said at least one laser diode and through which said at least one beam of light passes.
10. The device of claim 9, said micro lens comprising a cylindrical micro lens.
11. The device of claim 7, comprising a casing within which said at least one laser diode is positioned, said lens assembly comprising a focusing lens affixed to said casing and spaced from said at least one laser diode.
12. The device of claim 11, said lens assembly further comprising a collimating lens affixed to said at least one laser diode, said focusing lens being spaced from said collimating lens.
13. The device of claim 1, comprising a beam steering device constructed and arranged to direct said at least one beam of light to said at least two spaced locations on the surface plane.
14. The device of claim 13, said beam steering device comprising a beam steering optical element and a drive means for moving said optical element so

that said at least one beam of light is directed from a first location on the surface plane to a second spaced location thereon.

15. The device of claim 14, said drive means comprising a stepper motor, said optical element being selected from one of the group of optical elements consisting of a wedge prism and a tilted or angled plane.

16. The device of claim 15, further comprising a motor controller coupled to said stepper motor for control the movement of said beam steering device.

17. The device of claim 13, further comprising a controller coupled to said beam steering device, said controller being constructed and arranged to control the movement of said beam steering device to sequentially direct said at least one beam of light to said at least two spaced locations on the surface plane.

18. The device of claim 13, said beam steering device comprising a beam steering optical element, said optical element being selected from one of the group of optical elements consisting of a wedge prism, a tilted or angled plane, and a holographic plate.

19. The device of claim 1, said device being constructed and arranged to sequentially direct the beam of light to at least four spaced locations on the surface plane in a predetermined pattern.

20. The device of claim 19, said at least four spaced locations on the surface plane defining a predetermined pattern thereon.

21. The device of claim 19, each of the at least four spaced locations on the surface plane being spaced approximately eight hundred microns from each adjacent one of said at least four spaced locations thereon.
22. The device of claim 1, said light source and said lens assembly being fitted within a housing sized and shaped to fit in the hand of a device user.
23. The device of claim 22, further comprising a power supply within said housing for powering said light source.
24. The device of claim 22, further comprising a beam steering device positioned within said housing with respect to said light source, said beam steering device being constructed and arranged to direct said at least one beam of light to said at least two spaced locations on the surface plane.
25. The device of claim 24, further comprising a controller within said housing, said controller being operably coupled to said power supply, said light source, and said beam steering device, for triggering the emission of said at least one beam of light from said light source and for directing said at least one beam of light to said at least two spaced locations on the surface plane.
26. The device of claim 22, said light source comprising at least two laser diodes mounted to a mounting block positioned within said housing.
27. The device of claim 26, further comprising a controller coupled to each of said at least two laser diodes and adapted to sequentially operate each said laser diode with respect to the other for directing the beam of light to said at least two spaced locations on the surface plane.

28. The device of claim 1, said light source comprising at least two laser diodes mounted on a mounting block.

29. The device of claim 28, said light source comprising four spaced laser diodes mounted on a common mounting block.

30. The device of claim 29, each of said at least two laser diodes comprising a single active element laser diode chip.

31. The device of claim 30, each said laser diode chip being spaced approximately eight hundred microns from each adjacent one of said laser diode chips.

32. The device of claim 30, said laser diode chips being spaced apart from one another to form a predetermined pattern of beams of light directed to the surface plane.

33. The device of claim 28, comprising a microcontroller coupled to each said laser diode and adapted to sequentially operate each said laser diode with respect to one another for emitting said at least one beam of light and for sequentially directing said at least one beam of light to said at least two spaced locations on the surface plane.

34. The device of claim 28, said mounting block comprising a copper mounting block having a first planar surface, a spaced parallel second planar surface, and a plurality of sides adjoining one another and each said planar surface along their respective common edges.

35. The device of claim 34, each of said at least two laser diodes being mounted to a separate one of the sides of said mounting block.

36. The device of claim 34, comprising a separate insulated wire bonding pad on said mounting block for each respective one of said at least two laser diodes.

37. The device of claim 1, comprising a controller constructed and arranged to sequentially direct said at least one beam of light to said at least two spaced locations on the surface plane.

38. A method of generating a focused light beam directed to a surface plane, comprising:

- a) emitting at least one beam of light from a light source;
- b) passing the at least one beam of light through a lens assembly and focusing said at least one beam of light on the surface plane in response thereto; and
- c) sequentially directing the at least one beam of light to at least two spaced locations on the surface plane.

39. The method of claim 38, comprising the step of directing the at least one beam of light to a first location on the surface plane and then to a spaced second location thereon using a beam steering device.

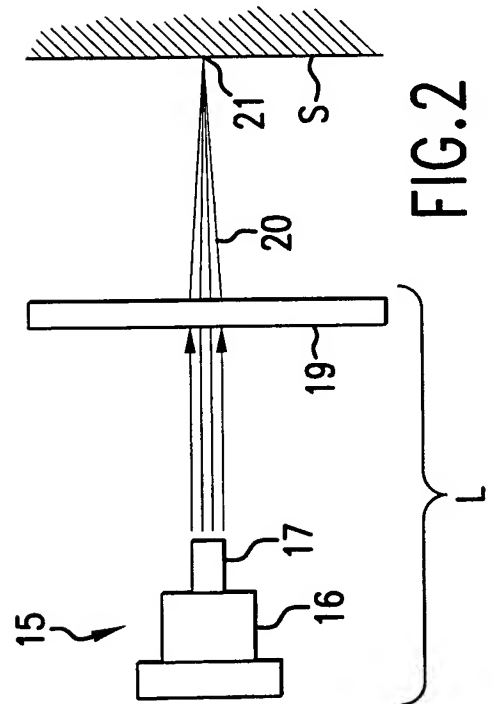
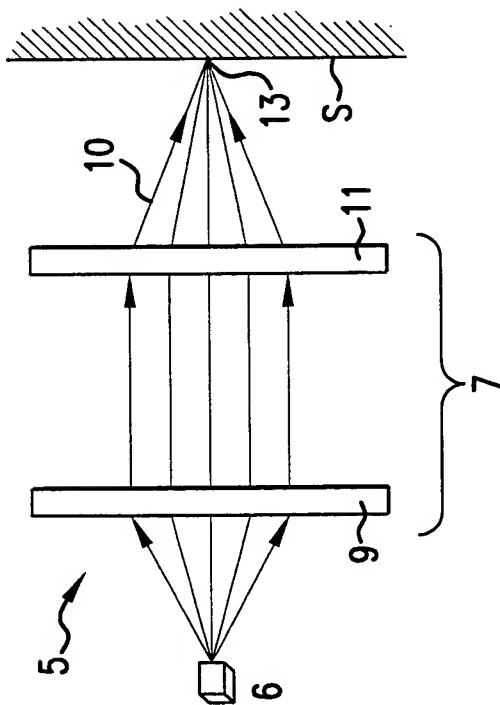
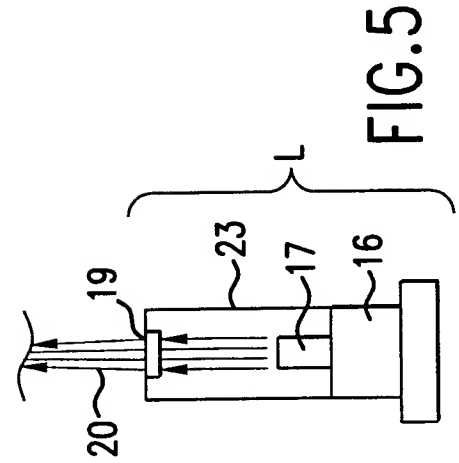
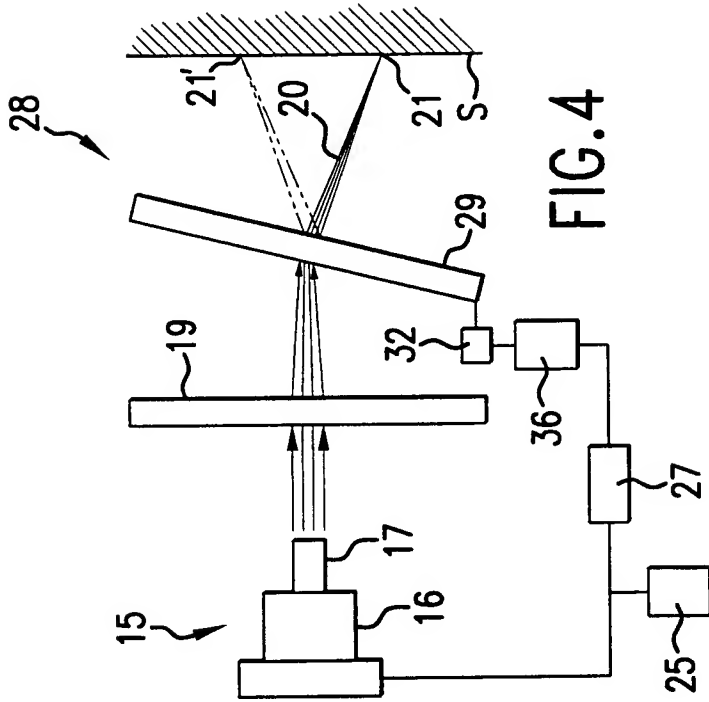
40. The method of claim 38, comprising the step of emitting at least two separate beams of light toward the surface plane using at least two spaced laser diodes.

41. The method of claim 38, comprising the step of sequentially directing the at least one beam of light to at least four spaced locations on the surface plane in a predetermined pattern.

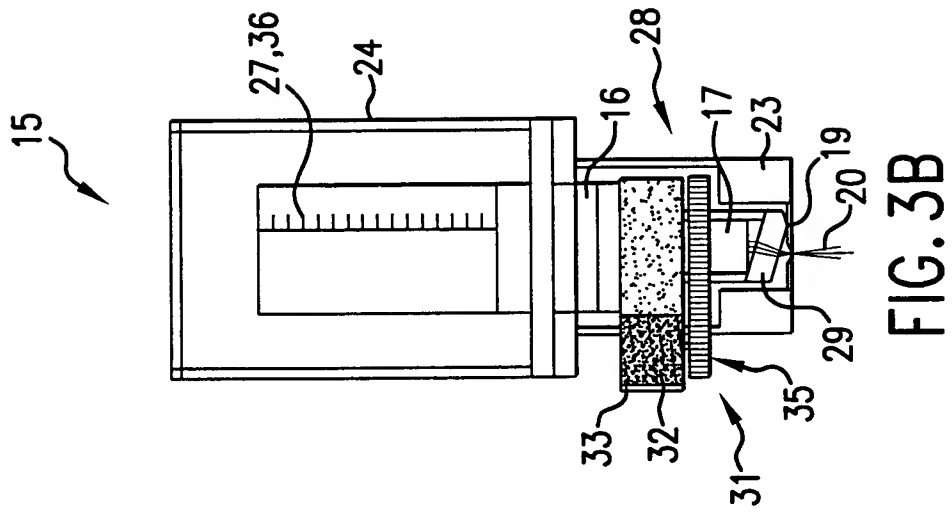
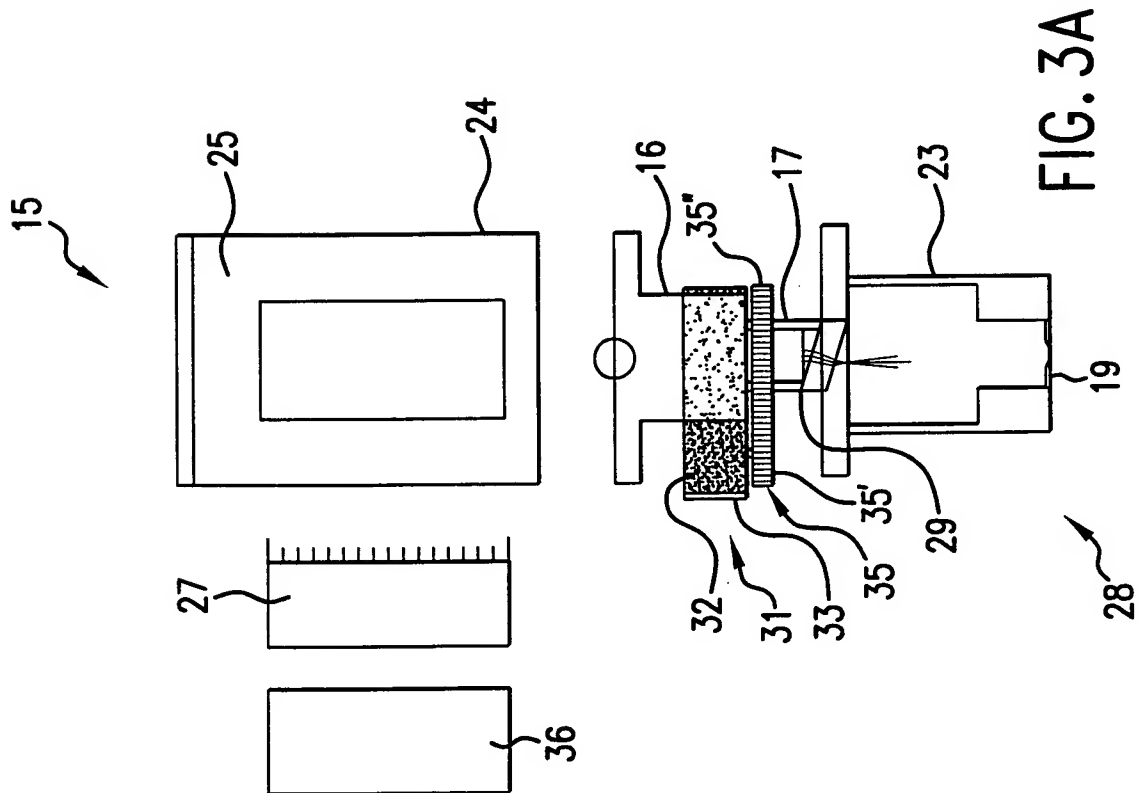
42. The method of claim 41, comprising the step of directing the at least one beam of light to each of said at least four spaced locations on the surface plane so that each said location is spaced approximately eight hundred microns from each adjacent one of said spaced locations.

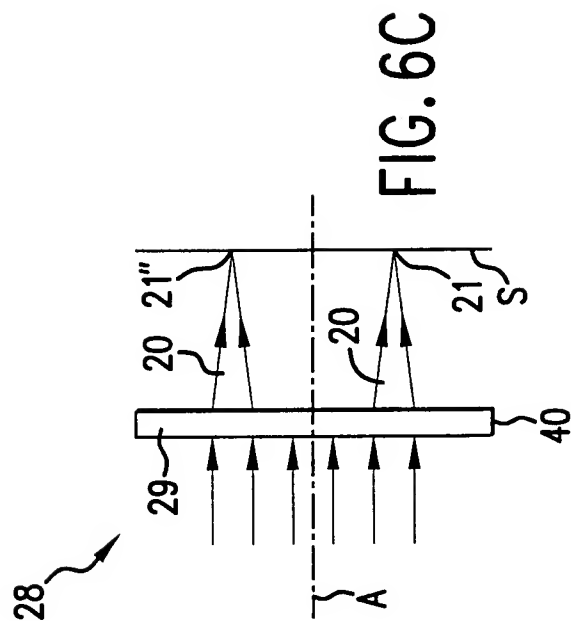
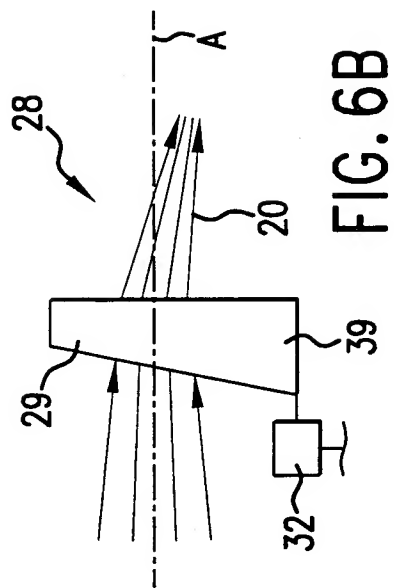
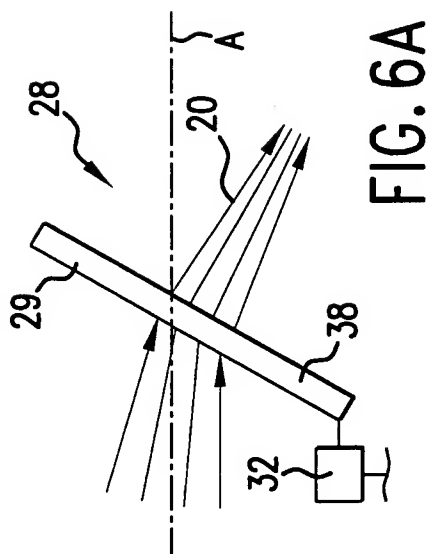


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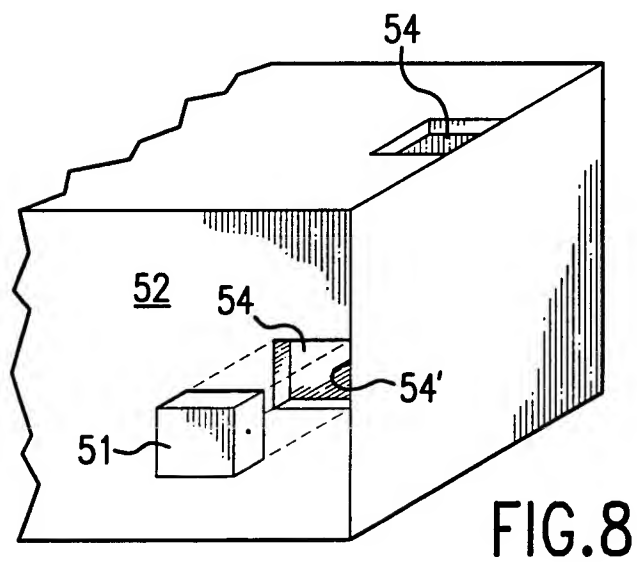
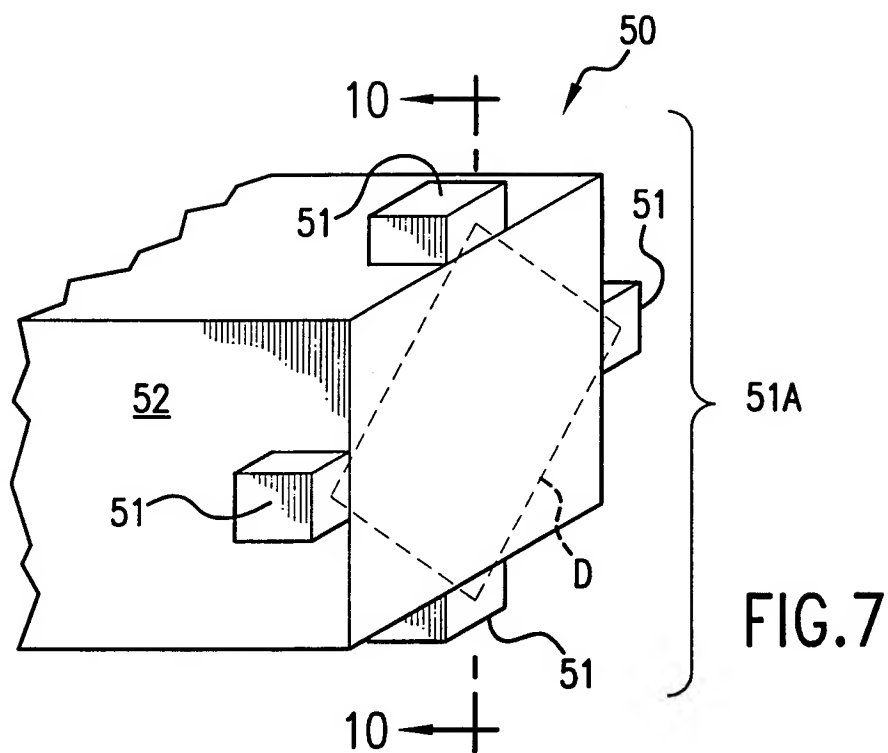


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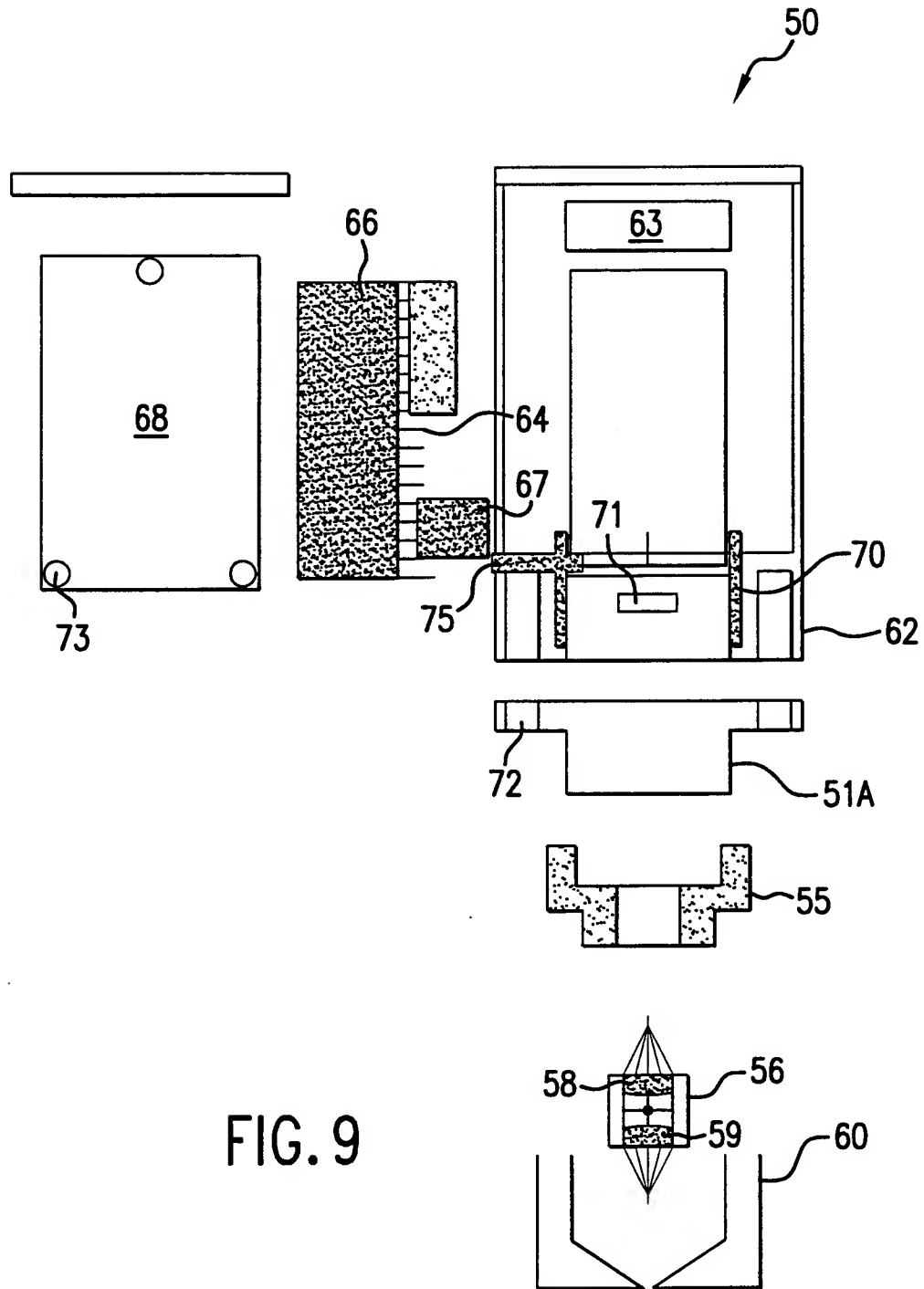
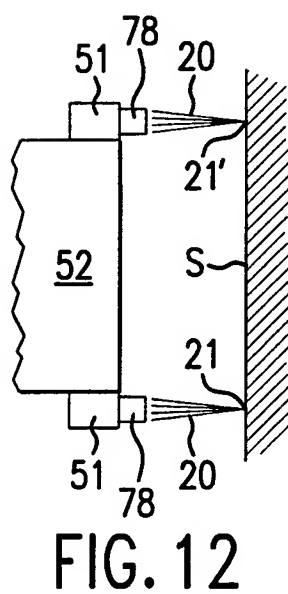
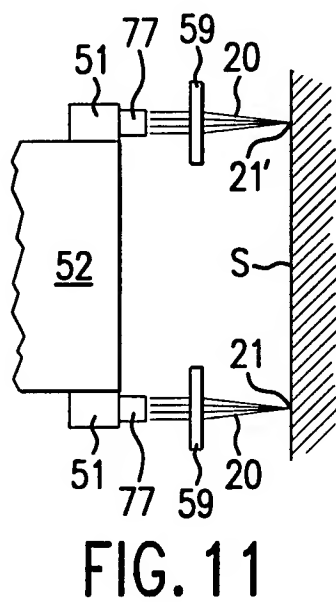
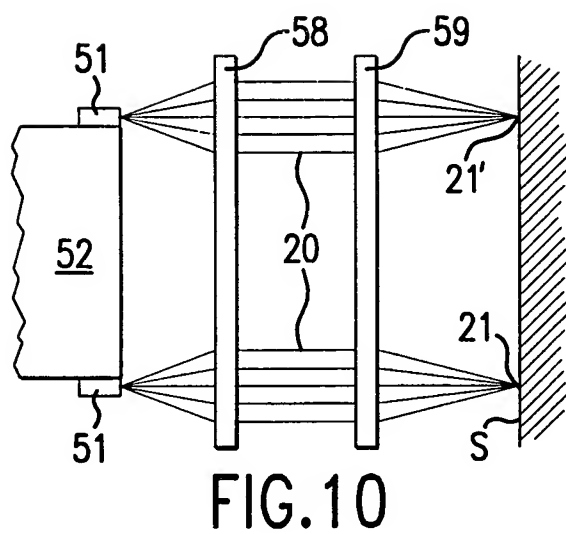
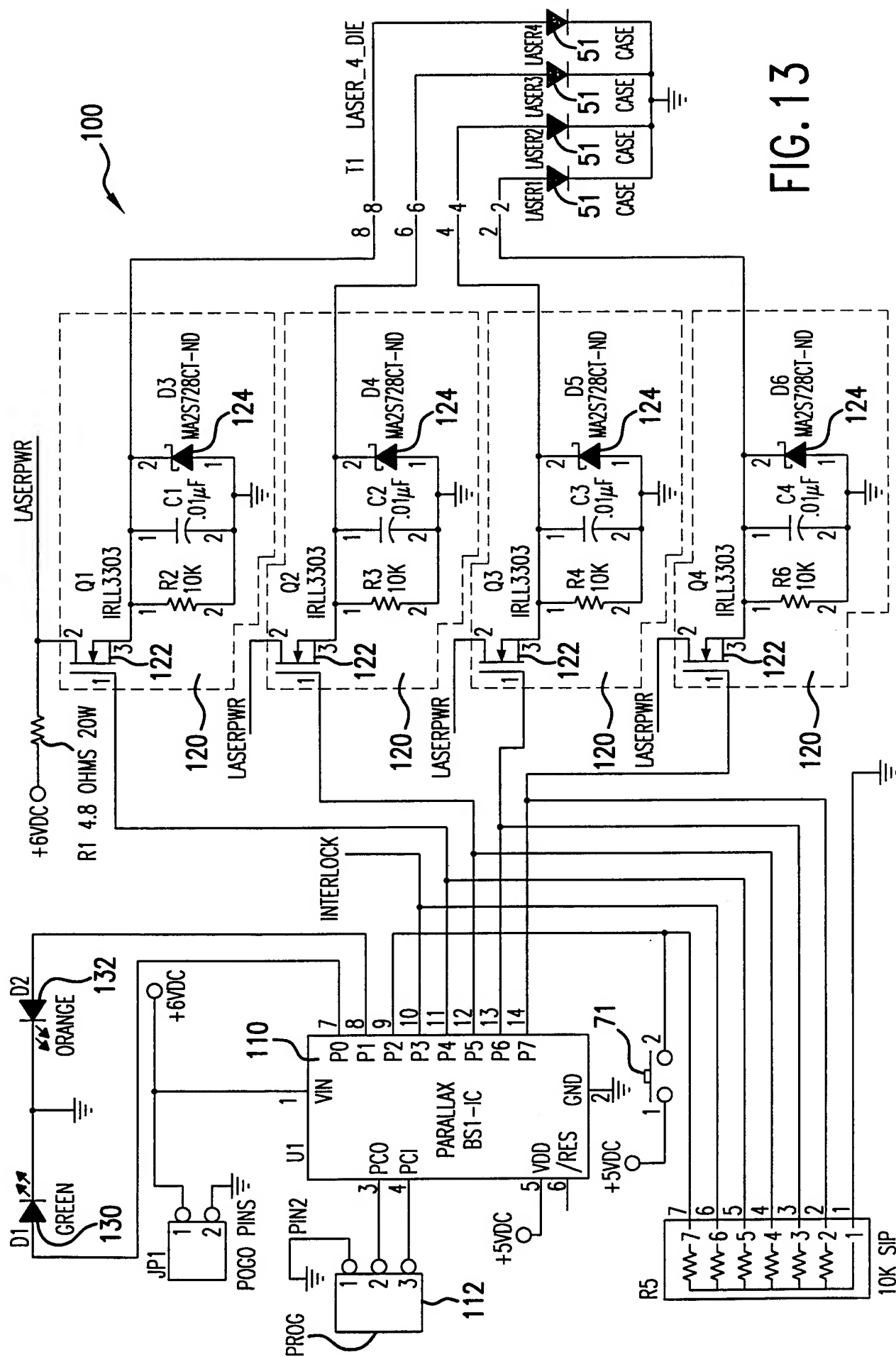


FIG. 9

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/16576

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61B18/20

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>WO 98 33444 A (TRANSMEDICA INTERNATIONAL INC) 6 August 1998 (1998-08-06)</p> <p>page 16, line 35 -page 17, line 25  page 18, line 30 -page 19, line 17  page 21, line 3 - line 27  page 31, line 23 -page 32, line 12  page 39, line 7 - line 29  page 46, line 25 -page 47, line 9</p> <p>---  -/--</p>	<p>1, 2, 7, 8,  13-20,  22, 23,  28-30,  38, 39, 41</p>

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

21 September 2000

Date of mailing of the international search report

28/09/2000

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# INTERNATIONAL SEARCH REPORT

Int. l. Application No

PCT/US 00/16576

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